Arizona
Department of Transportation

WORKBOOK

for

ASPHALTIC CONCRETE PAVING INSPECTION (Course Number 305)

a training course developed
for the

ARIZONA DEPARTMENT OF TRANSPORTATION
Phoenix, Arizona

by

ROY JORGENSEN ASSOCIATES, INC.
Gaithersburg, Maryland

Last revised by ADOT on September 9, 2003

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Directions to Workbook Users

Asphaltic Concrete Paving Inspection (Course Number 305) is one in a series of courses on inspection and quality control for bituminous highway construction. Other courses in the series include:

- Field Sampling and Testing for Bituminous Construction (Course 301);
- Prime, Flush and Tack Coats Inspection (Course 302);
- Chip Seal Coat Inspection (Course 303); and
- Asphaltic Concrete Plant Inspection (Course 304).

This course is designed primarily for highway construction inspection personnel, but it can also be used in training other personnel.

This Workbook is to be used in conjunction with discussion sessions with the trainee's instructor or supervisor, and other materials that make up the course. As sections of this Workbook are assigned, each trainee should:

1. Read and study the material to review previously presented information and gain additional details.
2. Complete the exercises and quizzes as they are provided.
3. Check his answers against those provided following the exercise or quiz.
4. Review the material as needed to correct and clarify any incorrect answers.
5. Discuss any areas that are still not dearly understood with the instructor or supervisor.

Each trainee is provided with a copy of this Workbook so that notes can be written in it and kept for future reference and review.

This course is based primarily on the standards established in the following Arizona Department of Transportation reference documents:

- These sections of the *Standard Specifications for Road and Bridge Construction*:
  - 406, "Asphaltic Concrete"
  - 407, "Asphaltic Concrete Friction Course"
  - 408, "Recycled Asphaltic Concrete"
  - 409, "Asphaltic Concrete (Miscellaneous Structural)"
  - 411, "Asphaltic Concrete Friction Course (Miscellaneous)"
  - 413, "Asphaltic Concrete (Asphalt Rubber)"
  - 414, "Asphaltic Concrete Friction Course (Asphalt Rubber)"
  - 416, "Asphaltic Concrete – End Product"
  - 417, "Asphaltic Concrete – End Product SHRP Volumetric Mix"
- Corresponding sections of the *Construction Manual*
- The "Asphaltic Concrete" section of Chapter IV of the Construction Manual, pages 56-102

Notes

First Discussion Period
(Introduction and Paving Equipment)

Section One: Introduction

This introductory section briefly reviews:

- Components and characteristics of bituminous mix
- Basic types of bituminous pavement courses
- Contract documents
- Pre-paving conference

Bituminous Mix

Bituminous mixtures consist of:

- Aggregates
- Asphalt cement
- Frequently mineral admixture

From the standpoint of the paving Inspector, the key characteristics of bituminous mix are:

- Gradation and other characteristics of the aggregates
- Content and particle coating of the asphalt
- Moisture content
- Temperature of the mix
- Specified proportioning of all materials in the mix
- Density of the mix after compaction

Bituminous Mix Pavement Courses

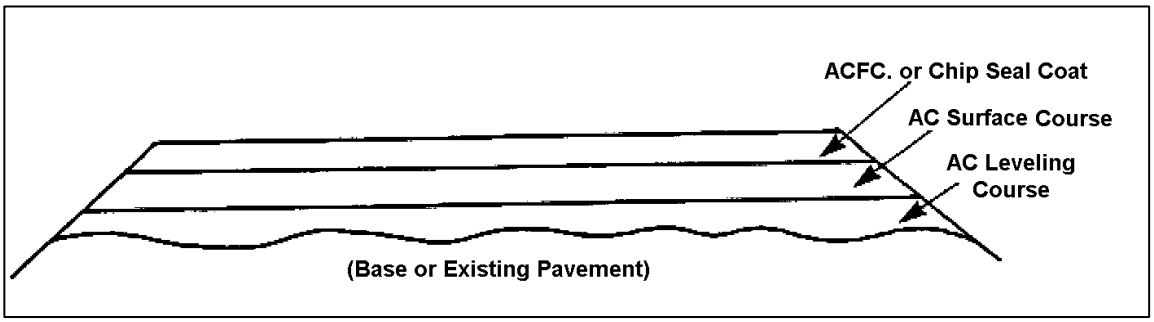
There are different types of bituminous mix depending primarily on its application. The primary types, defined in the *Standard Specifications* sections are:

- Asphaltic Concrete (AC) (Section 406),
- Asphaltic Concrete Friction Course (ACFC) (Section 407) and Miscellaneous ACFC (Section 411),
- Recycled Asphaltic Concrete (RAC) (Section 408),
- Asphaltic Concrete (Miscellaneous Structural) (Section 409),
- Asphalt-Rubber Asphaltic Concrete (AR-AC) (Section 413),
- Asphalt-Rubber Asphaltic Concrete Friction Course (AR-ACFC) (Section 414),
- Asphaltic Concrete – End Product (Section 416), and
- Asphaltic Concrete – End Product SHRP Volumetric Mix (Section 417).

Asphaltic Concrete

Asphaltic Concrete is used either as a:

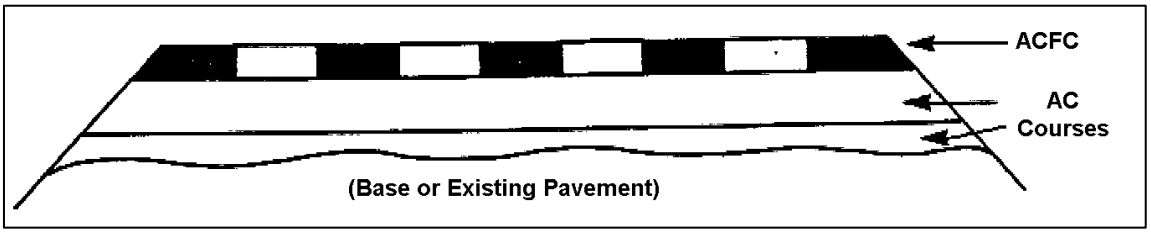
- Dense graded **leveling course** to raise an existing paved or unpaved surface to a smooth plane for other courses
- **Surface course** placed to serve either as the traffic surface or as a surface upon which a finishing course or seal coat is to be placed



Asphaltic Concrete will be specified as either ½-inch mix, ¾-inch mix, 1-inch mix, 1-½-inch mix, or Base Mix. The type of mix will be identified in the mix design.

Asphaltic Concrete Friction Course (ACFC) (Open Graded)

ACFC is an open graded bituminous mix used only as a final traffic-riding surface to provide a skid-resistant surface that reduces hydroplaning. The ACFC allows water to flow through the mixture and then off the roadway due to its open-graded nature.



In general terms, ACFC differs from other AC's in terms of:

- Its aggregates' gradation and other characteristics
- Its production and application temperatures
- Its relatively thin mat thickness of about ½" to ¾"
- Special considerations in its placement and compaction

Recycled Asphaltic Concrete

Recycled asphaltic concrete includes salvaged pavement as one of its component materials. It can be used in the same applications as Asphaltic Concrete - either as a leveling course or a surface course. From a paving standpoint, it is handled in the same manner as AC. The only significant differences are in its milling of the salvaged pavement from the roadway and its plant production.

Asphaltic-Rubber Mixes

Asphalt-rubber asphaltic concrete (AR-AC) and asphaltic-rubber asphaltic concrete friction courses (AR-ACFC) are mixtures of aggregate, asphalt rubber, and admixtures. The rubberized asphalt is formulated by mixing granulated rubber with asphalt cement to form a tough, elastic binder with less susceptibility to temperature changes and more resistance to oxidation age hardening. At the completion of the mixing and before being used, the asphalt rubber binder is processed in agitated tanks for one hour at temperatures between 325° and 375° F to allow time for reaction. The rubberized asphalt is substituted for the regular asphalt cement as the binder in the mix. This results in a more flexible and durable road surface but at a higher cost.

The major advantage of asphalt-rubber mixtures is their ability to retard reflective cracking when used as an overlay over badly cracked pavements. They are resistant to thermal stresses created by wide temperature variations and to tire chain wear. AR-AC (413) and AR-ACFC (414) are method specifications that require the Contractor to follow prescribed procedures on production placement, compaction, and equipment requirements.

Comparison of Mix Characteristics

The specifications give the standard characteristics and requirements of AC and ACFC.

There are differences between the base mix, SHRP (417 AC) mixes, and the other dense graded mixes (½" and ¾") is in terms of their:

- VMA range
- Aggregate gradation
- Percent of fractured coarse aggregate particles
- Uncompacted voids
- Flat and elongated particles
- Marshall Stability (for Marshall mixes only)

The primary differences between AC and ACFC are:

- Aggregate characteristics including:
  - Gradation (and gradation tolerances)
  - Fractured coarse aggregate particles
  - Flakiness index
  - Percent of limestone
- Temperatures

Contract Documents

There are several types of contract documents that provide requirements for paving operations. In case of discrepancy or conflict, the order in which they govern shall be as follows:

1. **Supplemental Agreement** provide the most detailed information for a specific project and govern over all other contract documents;
2. **Special Provisions and Addendums** provide additions or revisions to the Standard Specifications or contracts on individual projects.
3. **Project Plans** provide detailed drawings, tables, charts, etc., for a specific project;
4. **Standard Drawings** provide Departmental drawings for repetitive use, showing details to be used where appropriate.
5. **Standard Specifications** provide the most general requirements for all projects.

Pre-Paving Meeting

The primary objective of the pre-paving meeting is to establish a clear and mutual understanding of the work to be undertaken. Before any paving work begins, representatives of the Department and the Contractor meet to discuss and clarify such items as:

- Contractor's plan of operation and schedule
- Procedures and routes to be used for hauling materials
- Provisions for traffic control and safety
- Key points in the Special Provisions and Mix Design
- Equipment to be used and plans in case of equipment failure
- Discussion of quality control requirements, certifications for technicians, if required
- Joint construction
- Length of the ski
- Rolling procedures
- Number of rollers
- Compaction methods at areas that a roller cannot reach
- Asphaltic concrete temperatures
- Responsible parties for sampling and testing

The *Construction Manual*, section IV, page 60-61 can be used as a reference for the pre-paving meeting.

Section One Quiz

1. Asphaltic Concrete (as defined in Section 406, 409, 416, and 417 of the *Standard Specifications*) can be used as ... (Circle one or more)
   a. … A surface course which serves as a final riding surface.
   b. ... A leveling course.
   c. None of the above.

2. ACFC is used as ... (Circle one or more)
   a. … A final traffic-riding surface.
   b. … An intermediate course on which another course is placed.
   c. … A leveling course.
   d. None of the above.
   e. All of a, b and c above.

3. Recycled Asphaltic Concrete can be used in the same application as an ... (Circle one or more)
   a. … Asphaltic Concrete surface course.
   b. … Asphaltic Concrete leveling course.
   c. … Asphaltic Concrete Friction Course.
   d. None of the above
   e. All of a, b and c above.

4. ACFC differs from AC in that ACFC … (Circle one or more)
   a. … Has a higher application temperature than AC.
   b. … Has a lower application temperature than AC.
   c. … Has a higher fractured coarse aggregate particles requirement than AC except for base mix.
   d. … Has a higher sand equivalent requirement than AC.
   e. … Does not include portland cement or hydrated lime as a mineral admixture.
   f. … Is applied in a relatively thinner lift of ½" to ¾".
   g. … Is applied in a relatively thicker lift of 2" to 3".

Section One Quiz Answers

1. a. … A surface course which serves as a final riding surface.
   b. ... A leveling course.

2. a. A final traffic-riding surface.

3. a. Asphaltic Concrete surface course.
   b. Asphaltic Concrete leveling course.

4. b. Has a lower application temperature than AC.
   f. Is applied in a relatively thinner lift of ½" to ¾".

Section Two: Paving Equipment

This section discusses the equipment used in asphaltic concrete paving including asphalt distributors, haul trucks, paver, rollers, and other equipment and tools.

Asphalt Distributors

An asphalt distributor is used to apply tack to existing pavement in advance of the paving. The key characteristics of the asphalt distributor are:

- A storage tank to hold a sufficient supply of material including a gauge or other means of accurately determining the quantity of material in the tank;
- Heating system:
  - capable of heating and maintaining the asphalt at a specified temperature, and
  - with a temperature gauge;
- A circulation system with:
  - a pump to circulate the asphalt from the tank to the application equipment and back, and
  - a pressure gauge;
- Application equipment including:
  - a spray bar for applying bituminous material uniformly on variable widths of surface up to 15 feet;
  - pressure gauges, accurate volume measuring devices or a calibrated tank, and a thermometer for measuring temperatures of the tank contents;
  - a power unit for the pump and a spray bar which is adjustable laterally and vertically;
  - a method to continuously circulate the bituminous material through the tank and spray bar; and
  - a hand spray for small areas; and
- A means of monitoring the speed of the distributor, including a tachometer to display the speed in feet per minute.[1]

[1] For additional details on the requirements and inspection of asphalt distributors, see the course *Prime, Flush and Tack Coats Inspection* (Course 302) and Section 404-3.02 of the specifications.

Haul Trucks

The trucks used to haul bituminous mix to the paving site:

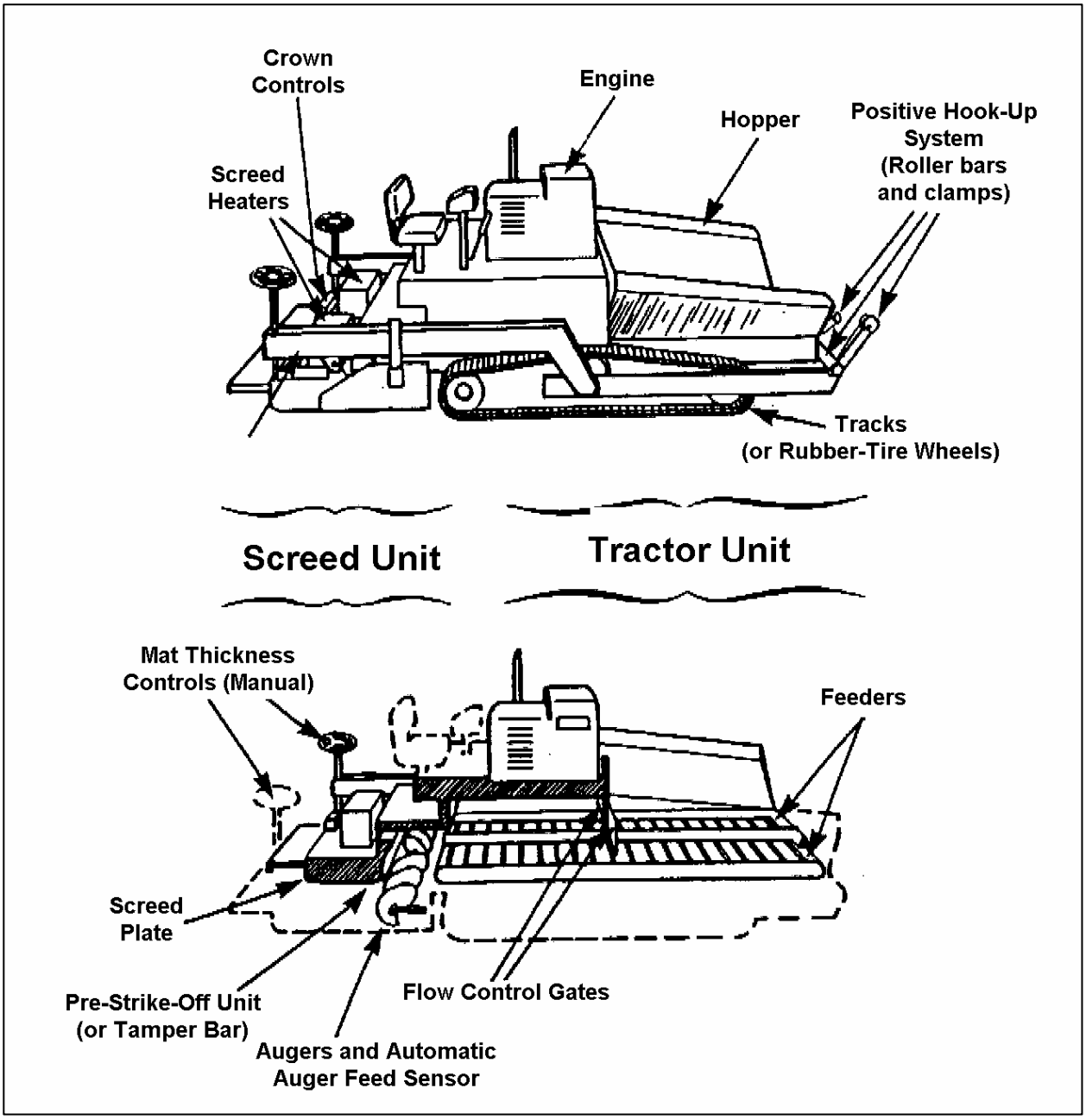
- Must have tight bodies with no holes or cracks (except a small temperature-check hole).
- Must be clean and free of foreign material, cold mix or diesel fuel (if the bed needs lubrication, an approved material – **not** diesel fuel – should be used).
- Should be equipped with a cover tarp to help retain the heat in the mix (particularly in cooler weather).

Either "end-dump" or "belly-dump" trucks may be used if:

- End-dump trucks are used, they must be capable of loading the mix directly into the paver without disrupting the paver's operation and should have:
  - tailgate chains to control the flow of the mix, and
  - a sufficiently long apron to reach the hopper of the paver and avoid spills, prevent excess weight on the tractor unit, maintain positive hook-up; and
- Belly-dump trucks are used, they must be capable of windrowing the mix in front of the paver in a manner that will enable the elevator machine (pick-up device) to pick up substantially all of the mix.

Pavers

The basic parts of a typical paver are shown in the illustrations below.



Paver Tractor Unit

The front tractor portion of the paver provides power for the paver, receives the mix and feeds it back to the screed unit.

The key functions and inspection points for the various parts of the tractor unit can be summarized as follows:

- **Engine** – Paver must be self-propelled with sufficient power to receive loads of mix (including pushing the truck when end-dump trucks are used).
- **Rubber Tires** – Must be properly inflated, or **Tracks** – Must be snug to avoid bumping.
- **Positive Hook-up System** (when end-dump trucks are used) – Used to push trucks and provide positive hook-up with trucks as they load directly to the paver.
- **Pick-Up Device** (when belly-dump trucks are used) – Must be capable of picking up and transferring substantially all of the windrowed mix to the hopper.
- **Hopper** – Receives mix and must be clean and free of cold mix, foreign material, or other contaminants, and have folding sides to empty mix onto the feeders.
- **Feeders** – Carry mix from the bottom of the hopper back to the augers and is capable of helping control the flow of mix by being turned on and off independent of the paver's speed, and having adjustable speeds.
- **Flow Control Gates** – Can be raised and lowered to help control the rate of flow to the augers and screed.
- **Augers**[2] – Distribute the mix in front of the screed and must distribute the mix uniformly across the width of the screed including any extension. Most pavers have an automatic auger feed sensor to ensure a full, even flow of material to the auger. Using sensors, the sonic control feeders regulate the amount of material in front of the screed.

[2] Although technically a part of and attached to the tractor unit, the augers function with the screed unit.

Paver Screed Unit

Although it is physically the smaller portion of the paver, the screed unit is functionally vital because it actually lays down and partially compacts the mix into a uniform mat.

The key functions and inspection points for the various parts of the screed unit can be summarized as follows:

- **Screed Pull-Arms** – Are attached to the tractor unit and pull the screed so that it floats over the mix being laid.
- **Pre-Strike-Off Unit** or **Tamper Bars** (depending on the type of screed) – Strikes-off and vibrates or tamps the mix at the front edge of the screed plate.
- **Screed Heaters** – Heat the screed plate to near the temperature of the mix to prevent sticking.
- **Screed Plate** – Floats over the mix and "irons" it into a uniform mat and must be:
  - Straight (check with a straightedge or stringline and watch for any warpage as it is heated)
  - Smooth and free of any nicks, gouges, ridges or other defects that would affect the mat
- **Crown Control** – Is the adjustable hinge at the center of the screed to form a flat or variably crowned mat?
- **Mat Thickness Controls** – Are used only in special situations approved by the Engineer, or when nulling the screed. The specifications require that the paver be equipped with automatic screed controls.

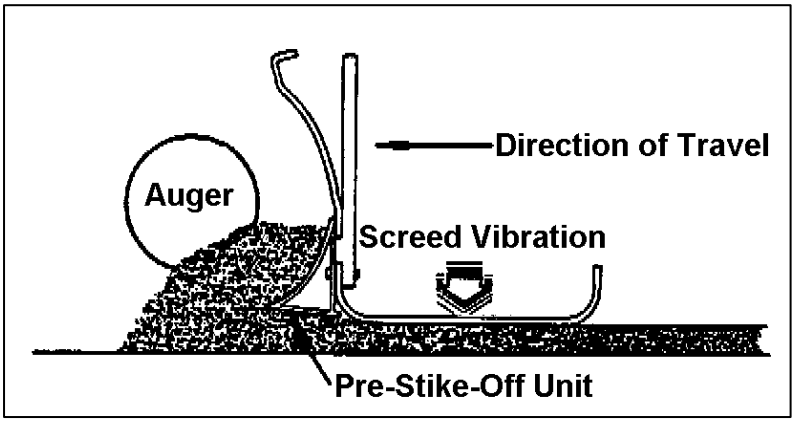
Due to the importance of the screed unit (and because many of its parts are hidden from view after paving begins), some additional inspection points are discussed and illustrated in the following sections.

Types of Screeds

There are two basic types of screeds:

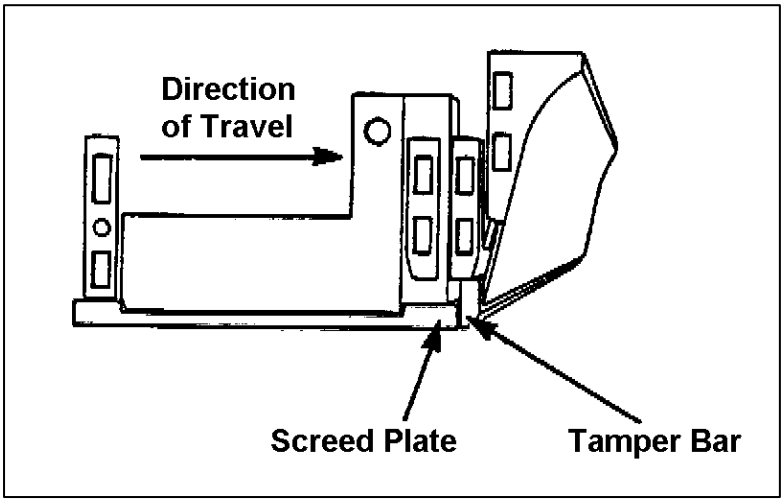
1. Vibratory screeds, which are most commonly used
2. Tamper screeds, which are not commonly used

Vibratory screeds are equipped with a vibrator to help partially compact the mix and often have a pre-strike-off unit attached to the front of the screed to help control the flow of mix under the screed.



When a vibratory screed is used, make sure that:

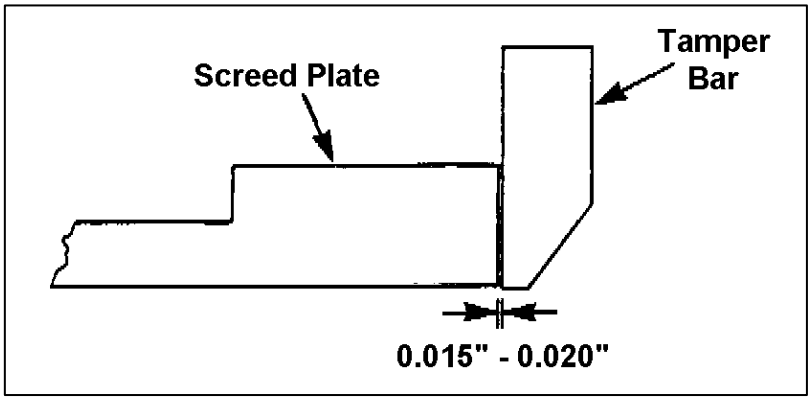
- Vibrators are in good operating condition along the full width of the screed.
- The pre-strike-off unit is in good condition.



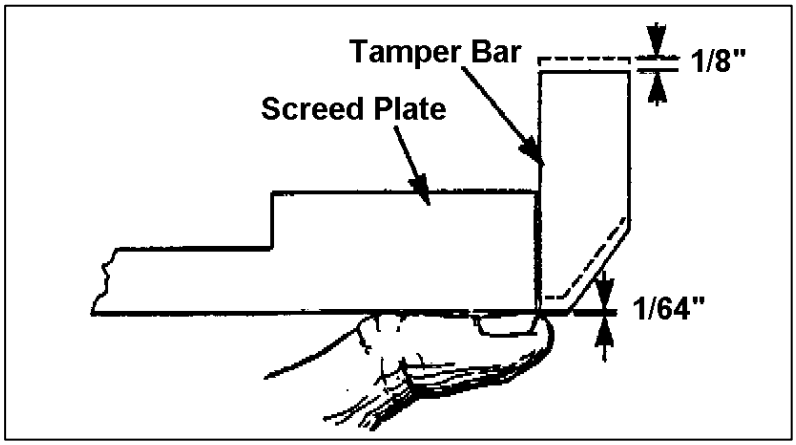
A tamper screed has a tamper bar along the front edge of the screed plate. The tamper bar moves up and down rapidly to push the mix under the screed and help partially compact it.

Make sure that the tamper bar:

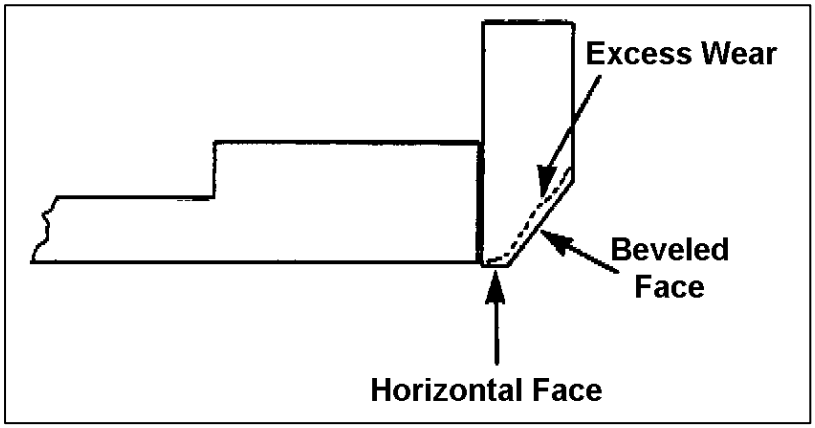
- Is straight.
- Clears the front of the screed plate by 0.015 to 0.020 inches to avoid deficiencies in the surface texture of the mat.



- Extends about 1/64th of an inch (about the thickness of a fingernail) below the bottom of the screed plate at the bottom of the tamper bar's stroke (about ⅛th of an inch).



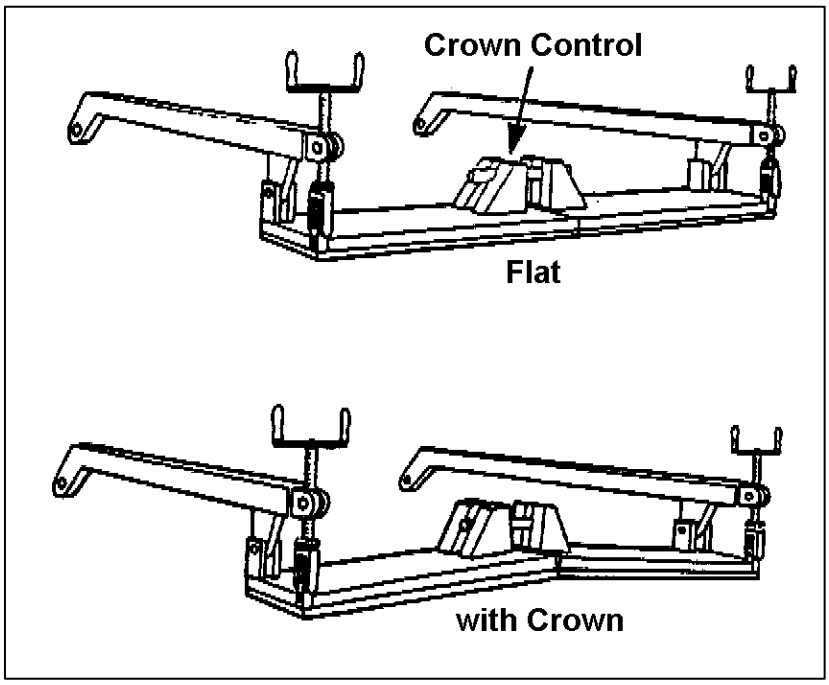
- Is not excessively worn to the extent that its horizontal face is no longer flat and



effective.

Crown Controls

The shape of the surface of the mat can be adjusted using the crown controls at the center of the screed. Such adjustments can make the screed either flat or with varying degrees of crown as illustrated below.

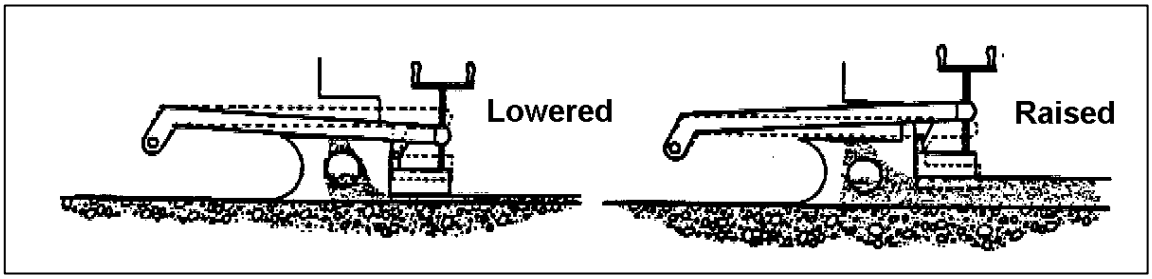


Many screeds have two separate crown controls – one at the front edge of the screed and one at the rear edge. The front crown control is often adjusted with slightly more crown than the rear edge in order to help minimize tearing or pulling the mat at the center of the screed.

Mat Thickness Controls

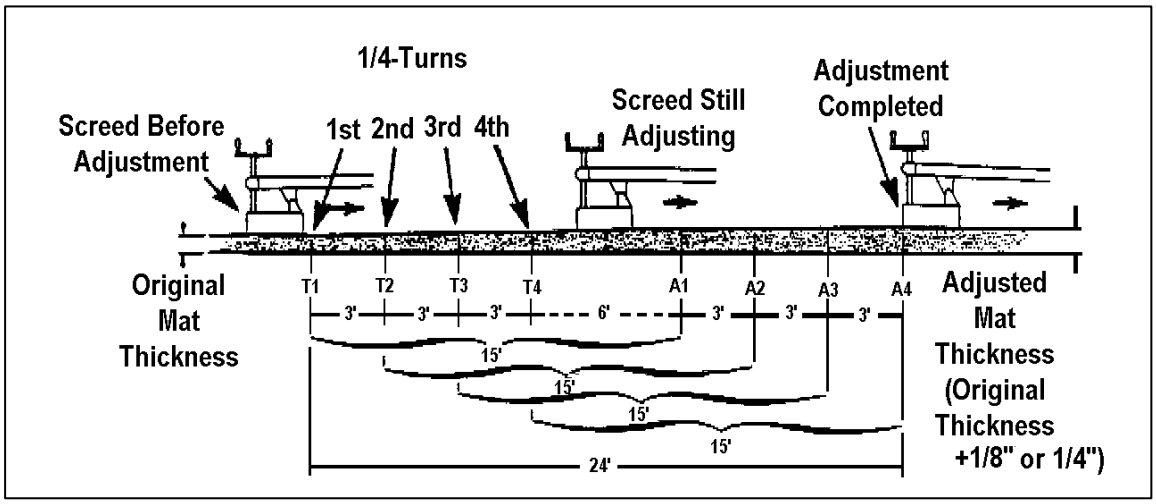
On most pavers, the thickness of the mat can be controlled and adjusted manually or automatically. In either case, the screed is:

- Lowered for thinner mats (as shown at the left below)
- Raised for thicker mats (as shown at the right below)



It is important to remember that any mat thickness adjustments made during operation can be made only **very gradually**.

For example, most pavers take about 15 feet (or more) to complete the adjustment from a ¼-turn of the manual mat thickness controls and it is usually necessary to wait for three feet of travel between each ¼-turn. If one full turn is needed to change ⅛ to ¼ inch of mat thickness, depending on the model, then it will take about 24 feet to accomplish the adjustment as diagrammed below.



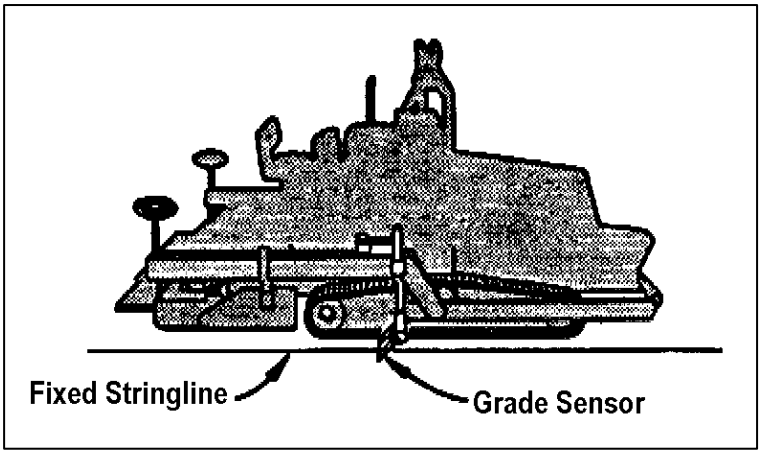
When a change is made in the screed's angle of attack, either at the screed or at the tow point, some pavers must move forward as much as 50 feet to fully complete the change.[3] Note that most of the adjustment occurs in the first 25 feet as shown above and that only about 10% of the change occurs in the last 25 feet.

This slow response of the screed is purposely built into the paver to avoid bumps in the pavement. However, it does make manual adjustment more difficult and less desirable, because there is a tendency to forget how long it takes and over-manipulate the manual controls.

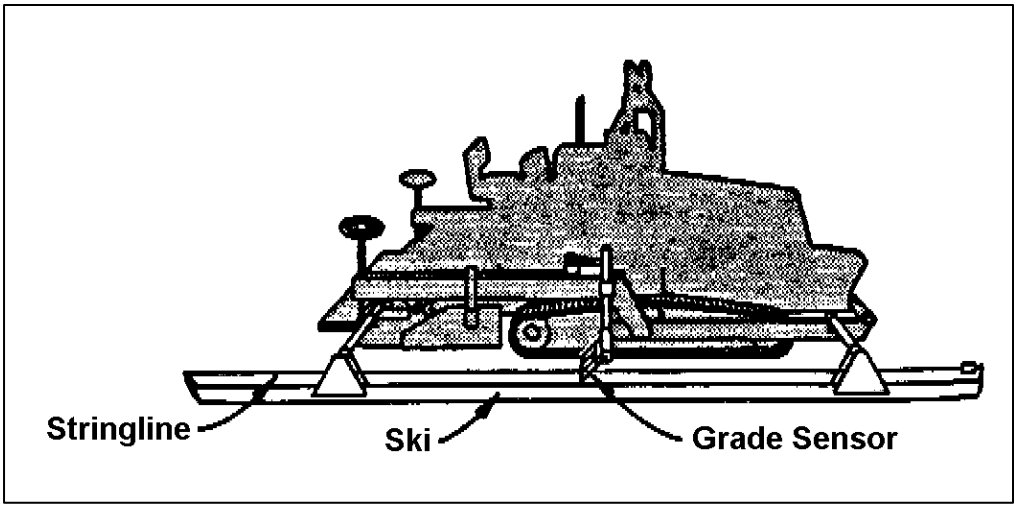
[3] See the *Hot-Mix Asphalt Paving Handbook 2000*, Section 15, page 144.

As a result, the Department requires the use of **automatic** controls that maintain the grade and mat thickness with either:

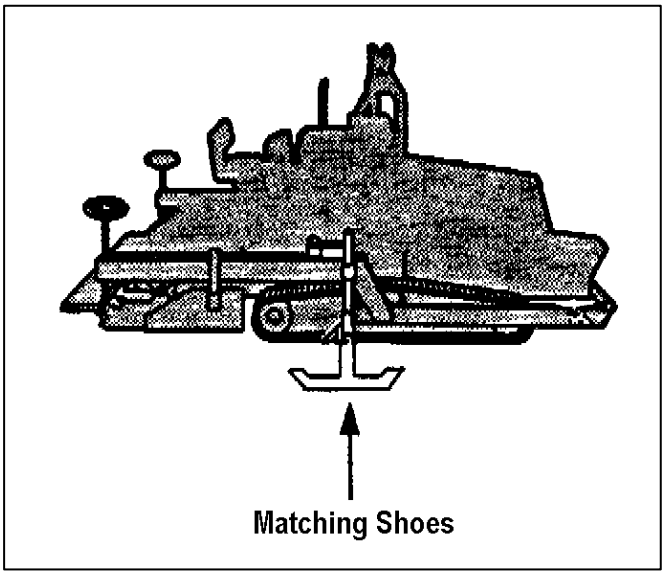
- A grade sensor that follows a fixed stringline **OR**



- A grade sensor used with a long ski that rides on an existing surface and carries its own stringline **OR**



- One or more short skis or matching shoes that ride on an existing surface.



Rollers

All rollers used for compacting bituminous-mix pavement must be:

- Self-propelled
- Capable of compacting mix without excessive crushing of aggregates
- Equipped with wheel-moistening systems using an approved material:
  - To prevent mix from sticking
  - Without using diesel fuel or other solvent
- Capable of smooth operation
  - At slow, steady speeds
  - Without any "backlash" in reversing
- **Operated in accordance with ADOT's specifications and the manufacturer's recommendations.**

Different types of rollers may be used within certain limitations as summarized below:

- **Steel-Wheel Rollers**
  - Are used either for initial, intermediate, or final compaction
  - Must be of a tandem-type
  - Must have smooth wheels
  - Must have an operating weight of at least eight tons
- **Vibratory, Steel-Wheel Rollers** may ***only*** be used if:
  - Nominal mat thickness is more than one inch
  - Surface temperature of the mat is at least 180° F
- **Pneumatic-Tire Rollers**
  - Are generally used for intermediate compaction
  - Must be of an oscillating-type
  - Must have at least seven pneumatic tires of equal size and diameter spaced for full coverage
  - Must have tires capable of being inflated to 90 psi of air pressure
  - Must be capable of an operating weight of not less than 5,000 lbs. per tire
  - Must be equipped with skirts to maintain the temperature of the tires during compaction

The Inspector should obtain and review the manufacturer's specifications for the makes and models of rollers to be used by the Contractor before paving and compaction work begins.

Other Equipment and Tools

Some of the other equipment and tools that may be needed in bituminous paving include:

- Small milling machine to cut in rumble strips on uniform spacing
- Motorgraders for blade-leveling to prepare an existing surface
- Power and hand brooms for cleaning the existing surface
- Hand tools such as lutes, rakes, shovels, and picks for hand work in small areas and joint construction
- Mechanical tampers for compacting small areas
- Various tools used by the Inspector

Section Two Quiz

1. An asphalt distributor used to apply tack for paving must … (Circle one or more)
   a. ... Have a capacity of at least 1,000 gallons.
   b. ... Be able to heat and maintain the asphalt at the specific temperature.
   c. ... Be able to provide a uniform application ranging from 0.03 to 1.00 gallons per square yard.
   d. ... Be manned with a bootman at the rear of the distributor during operation.

2. All haul trucks used to haul bituminous mix to the paving site must be ... (Circle one or more)
   a. … Clean and free of foreign material or cold mix.
   b. ... Lubricated with fuel oil.
   c. ... **A**n "end-dump-type" of truck.

3. End-dump haul trucks must be ... (Circle one or more)
   a. ... Capable of uniformly windrowing the material.
   b. … Able to load the mix directly into the paver without bumping or pushing the paver.
   c. … Used in conjunction with a pick-up device on the paver.
   d. ... Securely attached to the paver as the mix is dumped.

4. Which of the following potential variations in paver design would usually **not** be permissible unless authorized by the Engineer? (Circle one or more)
   a. Being self-propelled or towed
   b. With rubber tires or tracks
   c. With a vibratory screed or a tamper-bar screed
   d. Having a manual or automatic grade control system

5. The basic function of the augers on a paver is to ... (Circle one)
   a. … Carry the mix back from the hopper.
   b. … Re-mix the bituminous mix after it is laid down.
   c. … Spread the mix in front of the screed.
   d. … Strike-off the mix and partially compact it.

6. On a vibratory-type screed, which of the following is often used to control the flow of the mix under the screed plate? (Circle one or more)
   a. A ski-type of grade sensor
   b. A pre-strike-off unit
   c. A tamper bar
   d. The screed heaters

7. The Department requires the use of automatic grade controls on pavers in most situations primarily because ... (Circle one)
   a. … The screeds on most pavers react too quickly to manual adjustments for the operator to respond.
   b. … Very few pavers can be operated in a manual mode.
   c. … The screed responds so slowly to mat thickness adjustments that operators tend to get impatient and over manipulate the manual controls.
   d. ... Manual adjustments require more frequent checks of the mat thickness.

8. All rollers used in compacting bituminous pavement must be … (Circle one or more)
   a. … Static or vibratory steel-wheel rollers.
   b. … Self-propelled.
   c. … Equipped with an approved product to prevent the sticking of AC.
   d. … Equipped with skirts.

9. Vibratory steel-wheel rollers may only be used … (Circle one or more)
   a. … If they are equipped with skirts.
   b. … When the surface temperature of the mat is at least 180° F.
   c. … For mats with a nominal mat thickness of 1 inch or less.
   d. … For mats with a nominal mat thickness of more than 1 inch.

Section Two Quiz Answers

1. b. Be able to heat and maintain the asphalt at the specified temperature.
   c. Be able to provide a uniform application ranging from 0.03 to 1.00 gallons per square yard.

2. a. Be clean and free of foreign material or cold mix.

3. b. Able to load mix directly into the paver without bumping or pushing the paver.
   d. Securely attached to the paver as the mix is dumped.

4. a. Being self-propelled or towed (usually, must be self-propelled).
   d. Having a manual or automatic grade control system (usually, must be automatic).

5. c. Spread the mix in front of the screed.

6. b. A pre-strike-off unit.

7. c. The screed responds so slowly to mat thickness adjustments that operators tend to get impatient and over manipulate manual controls.

8. b. Self-propelled.
   c. Equipped with an approved product to prevent the sticking of AC.

9. b. When the surface temperature of the mat is at least 180° F.
   d. For mats with a nominal mat thickness of more than 1 inch.

Notes

Second Discussion Period
(Preparations for Paving)

Section Three: Preparations for Paving

Before paving operations begin, certain preparations must be made including:

- Establishing and checking alignment and grade controls
- Installing and maintaining work area traffic controls
- Ensuring that weather conditions are within the specified requirements
- Inspecting, repairing and cleaning the existing surface
- Placing tack coat (when needed)

Alignment and Grade Controls

It is the Contractor's responsibility to establish the alignment and grade controls needed for accurate horizontal and vertical placement of the pavement. The types of controls used depend largely on the type of paver and automatic sensors used.

In most situations (particularly when overlaying an existing pavement), the Contractor uses a long ski (a minimum of 30' is sometimes required), short ski, or matching shoes with an automatic grade sensor. These sensors ride on an existing surface to provide the grade control. Alignment control is usually provided by placing a stringline on the existing surface at the edge of the pavement.

Another approach combines the ski grade reference with a slope control device. The desired degree of slope is dialed into the controller, which maintains a constant cross-slope regardless of the resulting thickness of the mat being placed. The grade sensor on the ski references the grade on one side while the slope control device determines the grade on the other side.

The Inspector should see that the:

- Existing surface is sufficiently smooth and uniform for adequate grade control.
- Stringline is properly placed and followed for reasonably true alignment.

In some situations, such as for bridge approaches or when the existing surface is not sufficiently uniform, a raised stringline may be needed. See that it is at the correct height, adequately supported, and sufficiently taut to provide adequate control for both grade and alignment.

Traffic Controls

It is the responsibility of the Contractor to provide for the safe and effective control of traffic throughout the construction operations.

The Inspector should check the traffic controls before work begins – and as the work continues – to ensure that:

- The approved traffic control plan is properly implemented.

- Sufficient provision is made for traffic flow in terms of:
  - Adequate detours for full closures
  - Proper channelization for partial closures
  - Sufficient access to homes and businesses
- All traffic control devices are properly installed and maintained including:
  - Signs
  - Cones and barricades
  - Lights and flashers
  - Temporary pavement markings
  - Flagmen

Weather Limitations

Certain weather limitations must be met before any paving operations can begin:

- For Recycled Asphalt Concrete (RAC) lifts that are 1-½ inches or more in nominal thickness:
  - Work may begin only if the air temperature is at least 45° F and rising.
  - Work must stop if the air temperature is 50° F and falling.
- For all AC and RAC lifts less than 1- ½ inches in nominal thickness and ACFC, the temperature of the surface to be paved must be at least 65° F.
- For ACFC and AR-ACFC work is generally carried out only in certain seasons dependent on the average project elevation as shown in the chart below.

ACFC	Project Elevation	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
	0 to 3,499’		March 15 – June 1						Sept 15- Nov 15			
	3,500 to 4,999’			April 15 - Oct 15								
	5,000’ & above					Jun 1 –Sept 15						

AR-ACFC	Project Elevation	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
	0 to 3,499’		March 15 – May 31						Sept 1- Nov 15			
	3,500 to 4,999’			April 15 - Oct 15								
	5,000’ & above					Jun 1 –Sept 15						

- At any time, the Engineer may require the paving operations to cease due to adverse weather conditions.

Surface Preparations

Before any tacking or paving work begins, the Inspector should:

- Inspect the surface to be paved for such defects as:
  - Excessive moisture, frozen material, or other unstable material of the base
  - Severe cracking, loose slabs, or excessive joint material in existing concrete pavement or deck slabs
  - Potholes, bumps, cracks with a clear opening greater than ¼ inch, and severely deteriorated or unstable material in existing bituminous surfaces
- See that the Contractor properly repairs any of the above defects that are found.
- See that the Contractor cleans the existing pavement surface with power brooms and other tools as needed to remove any loose or foreign material that would hinder the adherence of the tack or bituminous mix.

Regarding the inspection and repair of existing surfaces, the Inspector should remember that asphaltic concrete is a relatively expensive item that:

- Should **not** be used in excessive quantities to level or smooth extensive irregularities that can be repaired.
- Will **not** correct unstable or excessively cracked materials that are left underneath it. This is an issue that should be brought to the attention of and discussed with the supervisor or project Resident Engineer.

Tack Coats

Tack coats are placed on old, existing pavement or previously placed new pavement courses, based on the judgment of the Engineer. Depending on the Engineer, the following tack coat options may occur:

- They may be omitted from new pavement surfaces (except prior to the placement of ACFC, AR-AC, or AR-ACFC).
- They may be placed on a previously primed or stabilized base course (usually when some time has passed and the base has become very dry).

When a tack coat is used, the Inspector should see that:

- The specified type and grade of material (AC or emulsion) is used:
  - Asphalt cement or emulsion (SS-1 is the most popular) under AC
  - Asphalt cement under ACFC, AR-AC, or AR-ACFC
- The temperature of the asphalt is within the range specified for the type and grade of asphalt.
- The specified application rate is followed for complete, uniform coverage.
- Only as much tack is applied that can be paved in the same day.

For more detailed information on tack coat requirements and inspection, refer to the course *Prime, Flush and Tack Coats Inspection* (Course 302).

Section Three Quiz

1. Which of the following should be checked for grade control in preparation for overlay of an existing pavement for which the Contractor will be using a long-ski-type of automatic grade sensor? (Circle one or more)
   a. Tautness of the stringline
   b. Length of the ski
   c. Smoothness and uniformity of the existing surface on which the ski will ride
   d. Height of the raised stringline

2. When a raised stringline is used for both alignment and grade control, the Inspector should check the stringline for ... (Circle one or more)
   a. ... Proper, uniform height.
   b. … Adequate support to minimize alignment irregularities in curves.
   c. … Sufficient tautness to minimize sagging that can cause grade irregularities.
   d. All of a, b and c above.

3. Providing for the safe and effective control of traffic during paving operations is primarily the responsibility of the … (Circle one)
   a. ... Department's Traffic Section
   b. ... Paving Inspector
   c. ... Local law enforcement officials
   d. ... Contractor

4. Which of the following weather limitations would apply when laying ACFC or AR-ACFC? (Circle one or more)
   a. The surface temperature must be at least 85° F.
   b. The work may start when the air temperature is at least 50° F and rising.
   c. The work may start when the air temperature is 40° F and rising.
   d. The work must stop if the surface temperature is below 75° F.
   e. The work must stop if the air temperature is 45° F or lower and falling.

5. Which of the following types of defects in an existing surface should be repaired before the surface is tacked for paving? (Circle one or more)
   a. Potholes
   b. Minor surface cracking
   c. Unstable base material
   d. Bumps and cracks with a clear opening greater than ¼ inch in an existing bituminous surface
   e. Areas where aggregates from an old chip seal coat have been lost

Section Three Quiz Answers

1. c. Smoothness and uniformity of the existing surface on which the ski will ride

2. d. All of a, b and c above.

3. d. Contractor

4. a. The surface temperature must be at least 85° F.

5. a. Potholes
   c. Unstable base material
   d. Bumps and cracks with a clear opening greater than ¼ inch in an existing bituminous surface

Notes

Third Discussion Period
(Inspecting Paving Operations)

Section Four: Inspecting Paving Operations

Three basic terms are used in bituminous paving operations:

1. **Mix Quantity** refers to the *weight* (tons) of the mix placed;
2. **Mat Thickness** refers to the *depth* of the mix in-place, including:
   - "Laydown" thickness before compaction (about 20 to 25% greater than the "plan" thickness)
   - "Plan" thickness after compaction as specified in the contract documents
3. **Spread Rate** refers to the *weight* of the mix used in relation to the *width, length* and *thickness* of the mat

The Inspector must verify that the Contractor:

- Maintains accurate records of the actual mix quantities used.
- Periodically checks the mat thickness.
- Calculates the spread rate.

Paver Preparations

Before paving begins, the Contractor usually needs to block-up the paver in order to make such preliminary adjustments as:

- Setting the angle of the screed
- Adjusting the crown controls, if necessary
- Setting the manual mat thickness controls and the height of the automatic sensors
- Starting the screed heaters so that the screed will be hot when paving starts.

Since much of the internal operation of the paver is hidden from view after paving begins, the Inspector must thoroughly inspect the paver at this time (as previously discussed in Section Two) for such items as the:

- Tautness of the track or the inflation of the tires
- Basic operation of the roller bars and damps, or pick-up device
- Cleanliness and operation of the hopper, feeders, and flow control gates
- Condition and full-width coverage of the augers
- Screed for the:
  - Condition of the pre-strike-off unit
  - Alignment tolerances
  - Condition and alignment of the screed plate itself

Mix Delivery

As the mix is delivered to the paving site, the Inspector must:

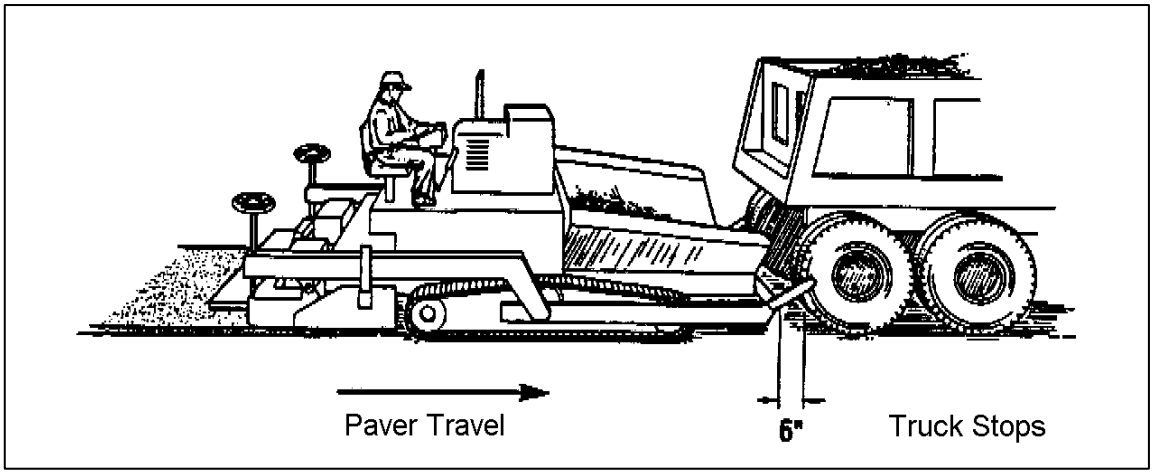
- Collect the weight tickets or ensure that the weight tickets are collected from the truck drivers:
  - Recording the location (station) and time received.
  - Keeping all weight tickets with the project records to summarize mix quantities when required, calculate the spread rates when specified, and submit them with the Daily Report.
- Spot-check the temperatures of random loads.
- Watch for indications of mix deficiencies such as:
  - Too hot (blue smoke) or too cold (stiffness)
  - Too much asphalt (shiny or soupy) or too little asphalt (exposed aggregates)
  - Poor aggregate gradation (too coarse, too fine or irregular), or segregation
  - Too much moisture (steam)
  - Contamination with foreign material

The Inspector should see that the mix is properly loaded into the paver in such a way that the smooth operation of the paver is not disrupted by the loading process.

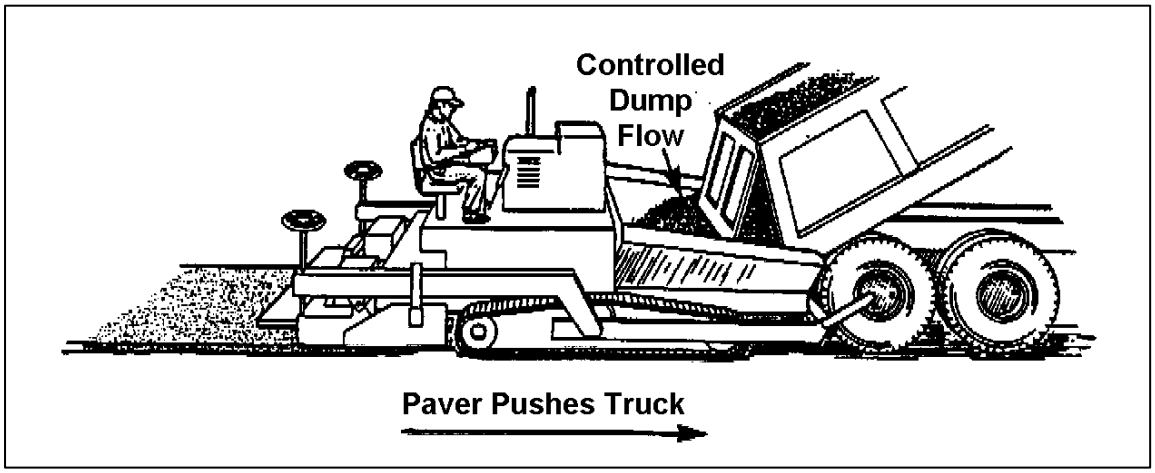
Using End-Dump Trucks

If end-dump trucks are used:

1. The truck backs into position, taking care to keep the truck straight so that both wheels will make contact at the same time.
2. The truck stops about six inches from the paver and waits (in neutral) for the paver to reach it.



3. As the paver makes contact with the back wheels of the truck:
   a. Clamps are closed to hook up the truck to the paver.
   b. Truck is moved forward by the roller bar pushing against the rear wheels.[4]
4. After the truck is hooked up to the paver, it discharges the load into the paver – taking care to control the dump flow so that it does not disrupt the paver's operation.



Using Belly-Dump Trucks

If belly-dump trucks are used, the paver must be equipped with a pick-up device and the Inspector should see that:

- Windrow of mix is properly aligned in front of the paver,
- Pick-up device removes substantially all of the windrowed mix from in front of the paver,
- the mix is loaded into the paver in such a way that the paver's operation is not disrupted by excessive loads or jerking, and
- for ACFC and RAC mixtures, the maximum windrow length in front of the paving machine is 150 feet.

[4] Some pavers may have another type of positive hookup device such as a clamp that attaches to a bar at the rear of the truck.

Mix Placement

The Inspector must closely monitor the placement of the mix in terms of:

- Paver's speed
- Any hand work done behind the paver
- Checking the temperature of the mix prior to compaction
- Checking the laydown thickness of the mat
- Checking the pavement cross slope
- Calculating the spread rate
- Adjustments to the mat thickness
- Quality of the mat surface
- Special considerations for paving in urban areas

Paver Speed

The paver should move at a slow-enough speed to avoid pulling or tearing the mat. The actual speed will vary with the equipment being used and the thickness of the mat being placed, but faster speeds generally increase the possibility of defects in the mat.

The Contractor should balance the paver's production rate with that of the plant and with the number of haul trucks being used. Imbalances can:

- Force the paver to stop and wait for the next load of mix, or
- Cause the haul trucks to wait until the paver is ready for more mix – which allows the mix in the trucks to cool off and stiffen.

Hand Work

Hand work behind the paver is **highly undesirable** because it is difficult to get the hand-spread mix to fully bond with the rest of the mat and still have a smooth, uniform surface. It is *particularly* undesirable for ACFC and AR-ACFC where the relatively thin mat and lower application temperatures magnify these difficulties. So, hand work is allowed **only** for small, minor irregularities. If an excessive amount of hand work is being done, it is usually an indication of defects in the adjustment of the paver or in the mix itself.

When hand work is done, it must be done properly by:

1. Taking mix directly from the hopper of the paver – **not** from a separate pile that may be cooler.
2. Lightly fanning it over the defect.
3. Immediately raking it into the mat so that it will bond.

Mat Temperature Checks

The temperature of the mat just prior to compaction must be periodically spot-checked at random locations and times. For each temperature check, record the temperature, location and time. Generally, the temperature prior to compaction should be:

Pavement	Minimum Temperature
ACFC & Misc. ACFC	200° F
AC (1-½" thickness or less)	250° F
AR-AC, AR-ACFC & RAC	275° F

Mat Thickness Checks

The laydown thickness of the mat must be periodically checked. This is usually done by the Contractor's personnel by:

1. Setting the collar of the probe to the desired laydown thickness. (Remember: "laydown" thickness = "plan" thickness + 20% to 25%)
2. Inserting the probe straight into the mat until the tip touches bottom.
3. Checking if the collar is:
   - Just touching mat = okay
   - Above mat = too thin
   - Sinks into mat before touching bottom = too thick
4. Repeating Steps 1 and 2 at several spots (at least right, left and center) for each check.
5. Recording the station number location and results in diary.
6. Notifying the Contractor that adjustments may be needed only if the mat is consistently too high or too low.

Mat thickness checks are used to monitor the *general* status of the thickness of the mat. The Inspector should remember that:

- Individual checks are not sufficiently accurate to warrant immediate adjustment.
- Over-adjustment of the thickness controls can create more significant problems in the surface of the mat.
- Any adjustments should be based on the calculated spread rates.

Calculating the Spread Rate

The Inspector must periodically check the quantity of mix actually being used in relation to the volume of the mat constructed. This spread rate calculation must be made at least every half-day of paving, in order to keep track of the mix quantities and make any necessary adjustments. Spread rate is a contract requirement under 416 and 417, but not 406.

The basic calculation procedure is to:

1. Determine the planned mix quantity for the area paved:
   - (length) x (width) = area (in square feet)
   - (area) x (plan thickness) = planned cubic feet
   - (planned cu. ft.) x (lbs./cu. ft.) = planned mix quantity (lbs.),
     where (lbs./cu. ft.) is the bulk density from the mix design
2. Determine the actual mix quantity:
   - From the scale house, **OR**
   - By totaling all weight tickets
3. Compare the planned and actual mix quantities of mix:
   - If the same → okay, thickness as planned
   - If actual is more than planned → mat is thicker than planned,
   - If actual is less than planned → mat is thinner than planned
4. Repeat the calculations at least each half-day and maintain a record of the accumulative planned and actual quantities of mix used.

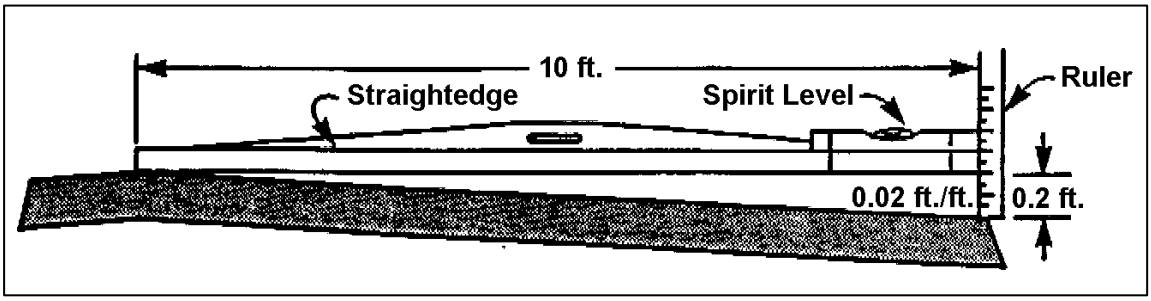
If the difference between the planned and actual quantities is significant, some adjustment in the mat thickness may be needed – in order to avoid paying for more pavement than needed or ending up with a pavement that is not structurally adequate.

Placement of 416 and 417 mixtures is governed by a spread lot pay factor. When the actual spread quantity varies by more than -2.0 percent from the required quantity, a penalty table is provided in the specification. If the variance is more than -12.0 percent, the spread lot (½ shift of production) is rejected. If the quantity varies more than +5.0 percent, no payment will be made for material which exceeds +5.0 percent.

Cross-Slope Checks

It is also sometimes necessary to periodically check the cross slope of the mat as it is laid. When overlaying an existing pavement, the cross slope of the old surface is usually reliable enough that cross slope checks are not needed very frequently. However, on new pavement construction, cross-slope checks should be made frequently enough to find and correct any deviations before they become serious problems.

To check the cross slope of the mat, you can use a straightedge with a spirit-level attached to the end and a ruler to measure the cross slope as shown below.



For each cross-slope check:

- The straightedge is placed across the pavement.
- Hold the end of the straightedge so that it is level.
- Measure the vertical distance from the end of the straightedge to the pavement.

Using a ten-foot straightedge as shown above, a 0.02 ft./ft. cross-slope should result in a 0.2-ft. measurement at the end.

Mat Thickness Adjustments

Occasionally, adjustments may be needed to the thickness of the mat, but adjustments should not be made too quickly or too frequently.

Adjustment problems are particularly critical when the screed is operated by manual mat thickness controls because the paver takes about 15 to 18 feet to fully make the change from a small adjustment to the manual controls of only ¼-turn. Too often, the laborer operating the manual controls tends to make "waves" in the pavement by over-manipulating the controls.

The numbers and adjustment descriptions below correspond to the illustration on page 38.

① The screed operator checks the depth and finds it too thin.

② So, the operator turns the control to raise the screed.

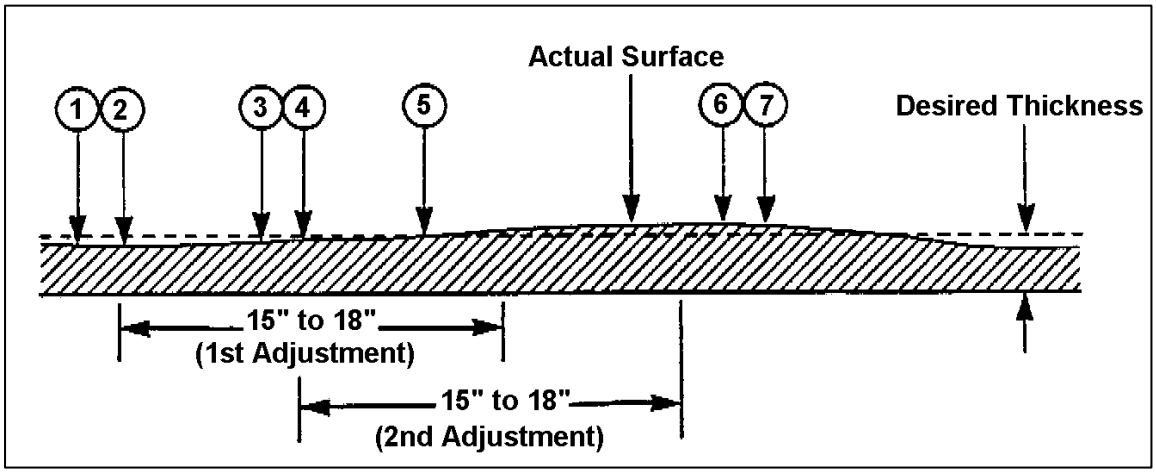
③ The operator then re-checks the depth and it is still too thin (because the screed is still adjusting).

④ So, the operator turns the control to raise the screed more.

⑤ The operator re-checks the depth and finds it okay (but the screed is still adjusting).

⑥ When checking the depth again, the operator finds it too thick.

⑦ So, the operator reverses the adjustment ... and so on, in an up-and-down pattern of "waves".



So, pavers **must** have automatic screed controls. Most automatic control systems allow the paver to be operated in a:

- Fully automatic mode (both sides, automatic)
- Semi-automatic mode (one side, automatic and one side, manual)
- Manual mode (both sides, manual)

However, the semi-automatic and manual modes must be avoided unless authorized for special circumstances by the Project Engineer.

Automatic screed controls practically eliminate the problems of over-manipulating the mat thickness, but when an adjustment is needed during automatic operation:

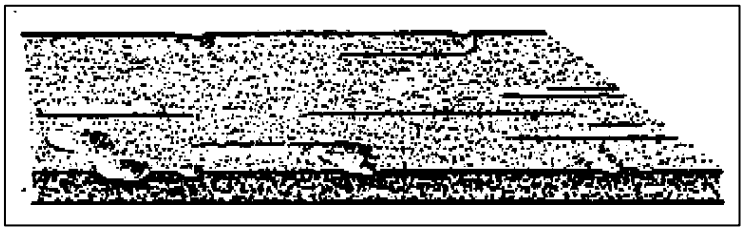
- It is best to adjust the sensor control screw.
- The grade control knob on the command panel may be used, but this is usually more difficult.
- **Never adjust** the manual controls during automatic operation.

Mat Quality

The Inspector must check the general quality of the surface of the mat behind the paver. The surface should be smooth and uniform across the full width of the mat – including any extensions.

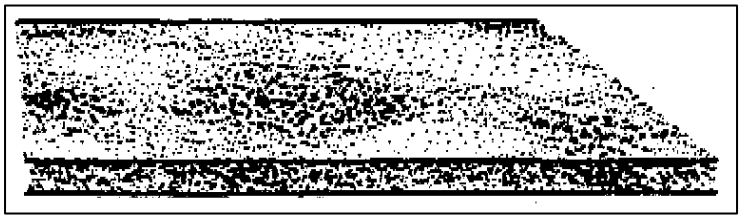
There should **not** be any:

- Streaks, gouges, or holes



- Slick or rocky spots

- Spots of coarse or fine aggregates (rock or sand "pockets") or spots that are rich or lean with asphalt



If such defects occur, notify the Contractor so that the problem can be determined and corrected.

Paving in Urban Areas

The Inspector should also see that special care is taken when paving in urban areas including:

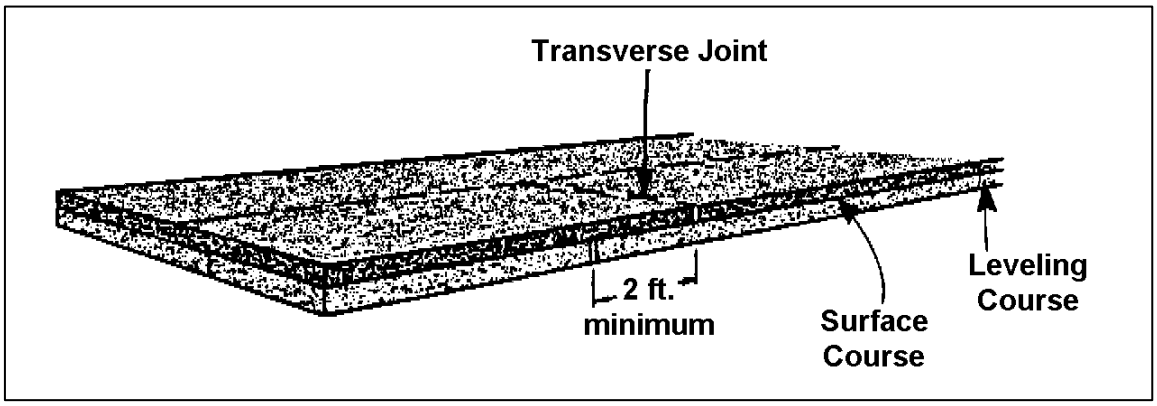
- Additional consideration of the higher volumes of traffic in traffic control, particularly in providing:
  - For adequate flow of traffic (full closures are usually not feasible)
  - Access to homes and businesses
- Special attention to protecting adjacent structures and property
- Placement of mix around manholes, drainage inlets, etc.
- The relationship of the pavement with curb and gutter:
  - The last AC course should be flush with the gutter after compaction.
  - ACFC (and chip seal coats) should be above the gutter after compaction.

Joint Construction

Both transverse and longitudinal joints must be properly constructed. Poorly constructed joints in bituminous pavements usually result in bumps or ridges in the riding surface or cracking that can lead to further deterioration of the pavement.

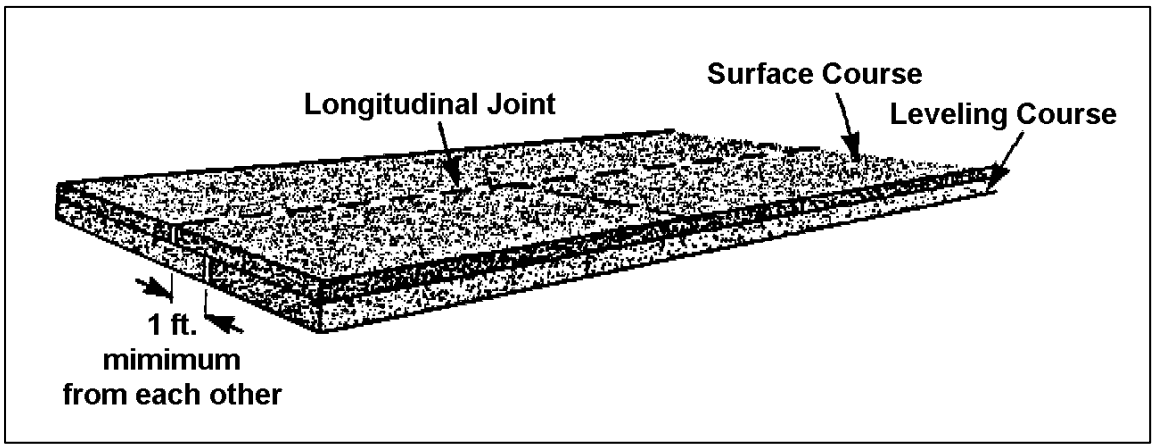
Joint Offsets

Although not required by the specifications, the transverse joints in successive lifts of pavement should be at least two feet apart.



The longitudinal joints in successive lifts must be:

- At least one foot apart
- Within one foot of the centerline of the lane or between two lanes

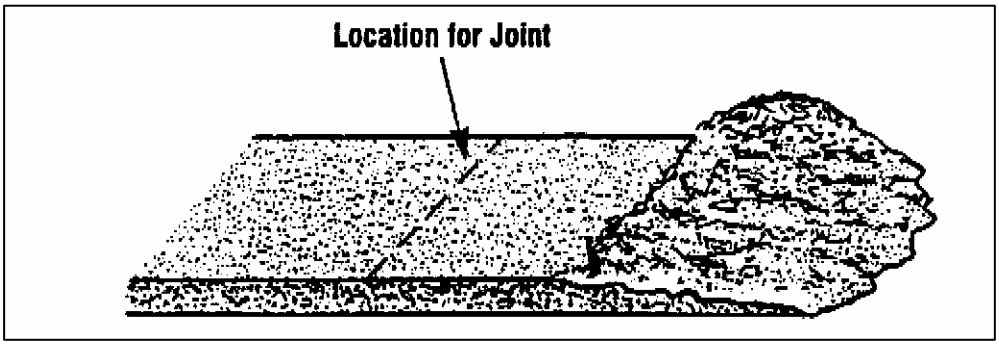


Transverse Joints

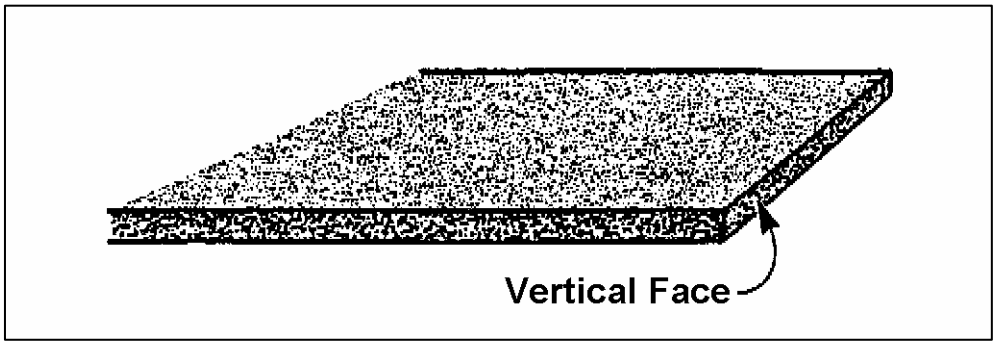
Transverse joints are constructed whenever paving operations stop at the end of the day, or due to bad weather or for other reasons. The procedures for constructing a transverse joint follow.

At the end of the paving:

1. The paver leaves a rough, uneven end. Locate the position of the joint so that it is well back from the rough, unscreeded end of the mat.



2. The uneven end is cut away leaving an edge with a vertical face.

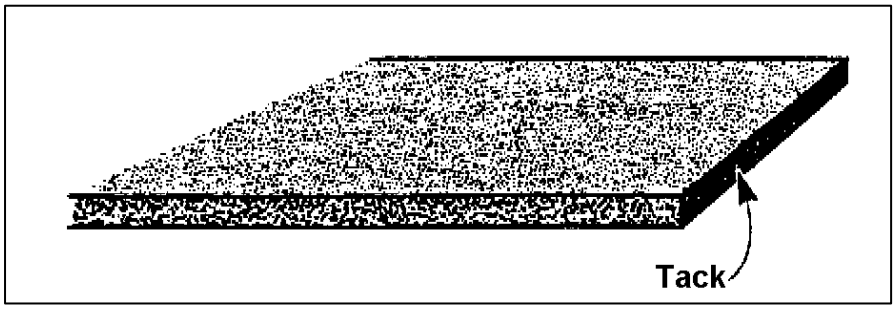


3. Paper, or a board of the appropriate thickness, is placed along the vertical face and a smooth tapered end is constructed and compacted. Do not use dirt.
4. The mat and taper are then compacted all the way through the end of the taper.

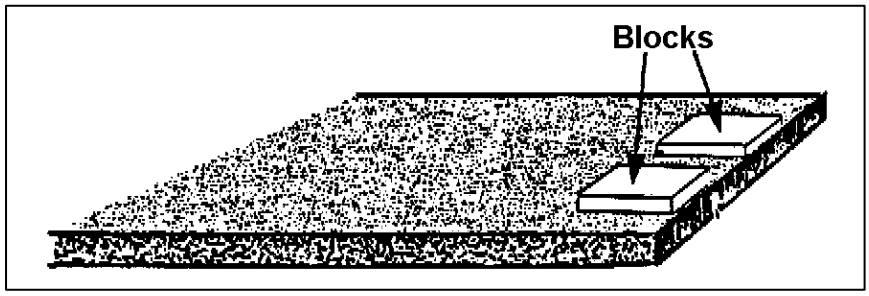
When paving resumes:

5. Before removing the temporary taper, the mat next to the joint should be straightedged to be sure than it is level and uniform up to the joint. If it is not uniform, a new vertical face will have to be cut further back.
6. The tapered end and paper or board are removed and wasted, leaving the vertical face.

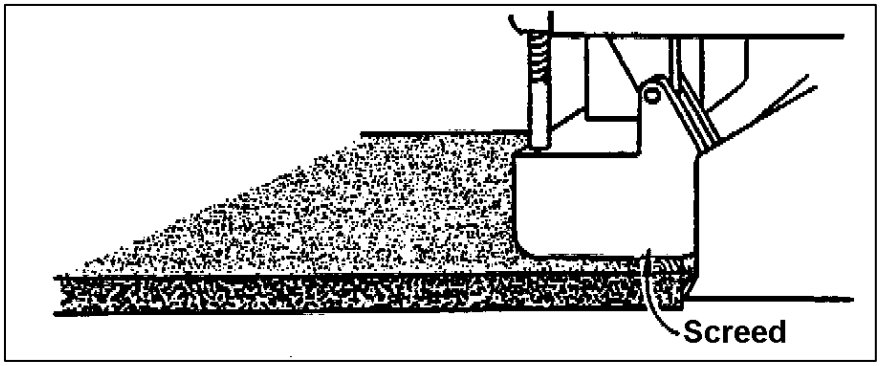
7. The vertical face is then tacked.



8. Blocks or boards of the appropriate thickness (the difference between the compacted and uncompacted mat thicknesses) are used to block up the screed to the correct height for the uncompacted mat.

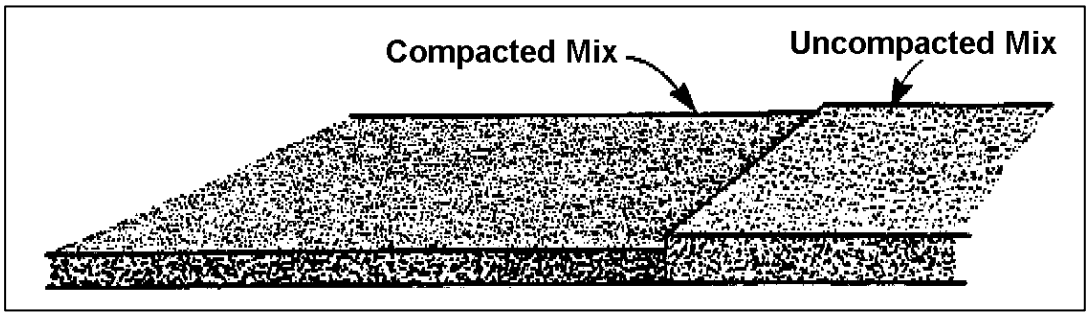


9. The paver is moved into place so that the screed is positioned over the joint at the correct height.

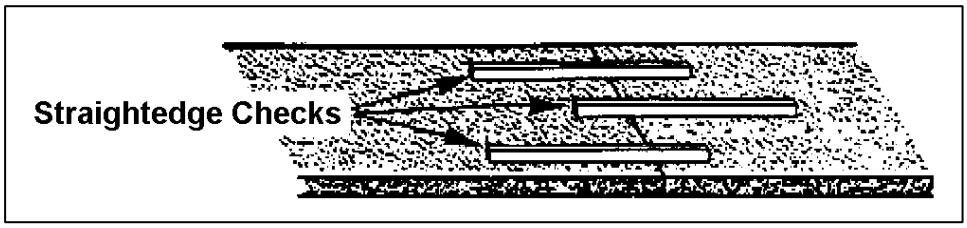


10. The paver remains in this position to fill the space with mix before starting forward.

11. The paver then moves forward and any hand work that may be needed is done for the uncompacted mat.



12. After the joint is compacted, it is straight-edged at several positions to ensure a uniform pavement surface.



Longitudinal Joints

Longitudinal joints are formed between two adjacent lifts of pavement. The joints may be:

- Vertical joints – if the first pass is still hot when the adjacent lift is placed (this requires either two pavers operating in echelon or an extremely short section)

1st Pass (still hot)	2nd Pass
Vertical Longitudinal Joint	

- Sloped joints – formed with a slope shoe attached to the paver when laying the first pass.

1st Pass (hot or cold)	2nd Pass
Sloped Longitudinal Joint	

However, it should be emphasized that the:

- Vertical joint can only be used when the first pass is still hot.
- Sloped joint must be used when the first pass is cold.

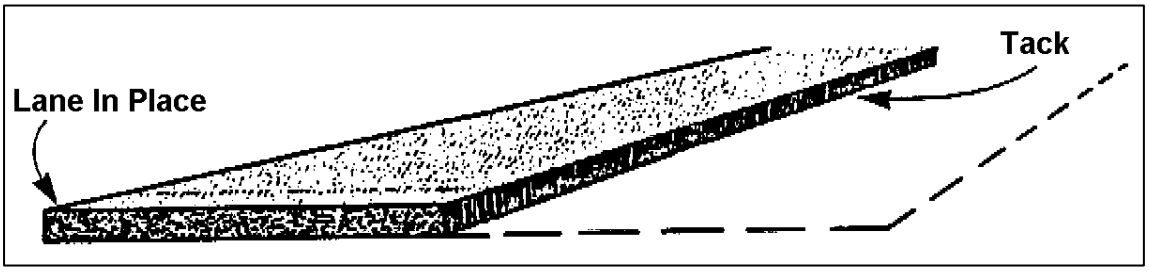
The basic procedure for constructing a longitudinal joint (with emphasis on the sloped joint) is as follows.

When the first lift is placed:

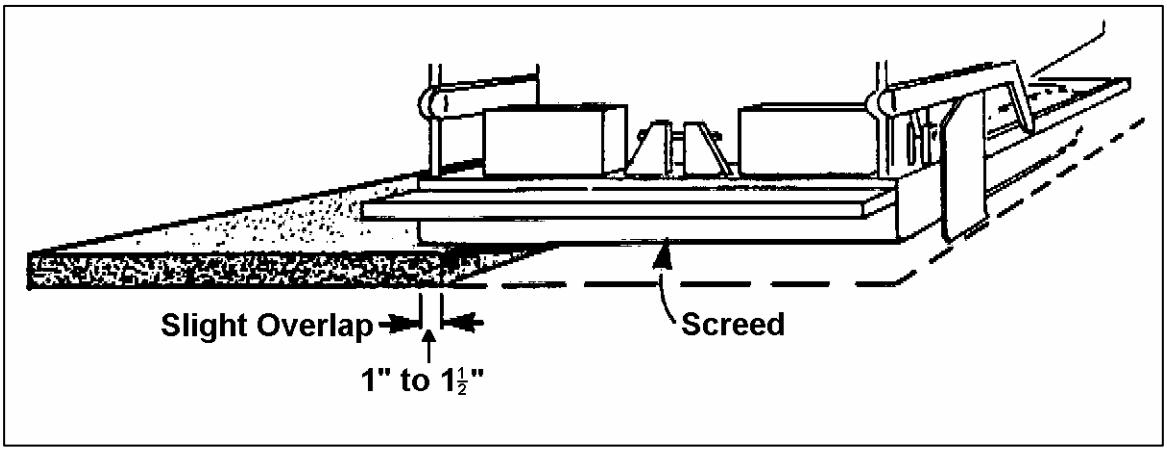
1. The pass is laid down – preferably using a slope shoe (4:1 to 6:1 slope depending on the thickness of the mat).
2. The sloped edge of the mat is compacted.

When the second adjacent pass is placed:

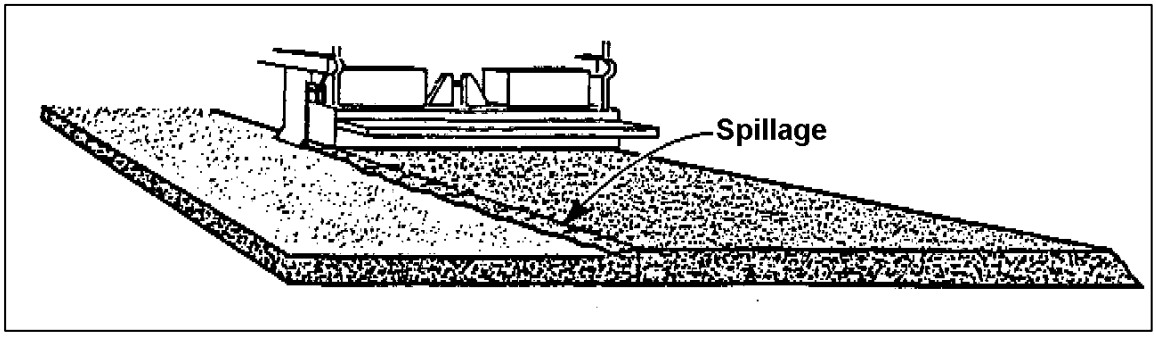
3. The edge of the first pass may need to be tacked (but not if first pass is still hot).



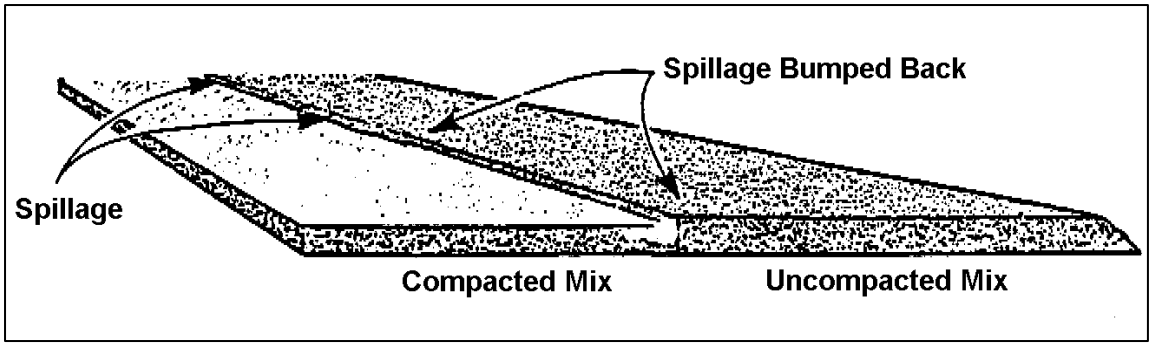
4. The paver positions the screed with a slight overlap on the first lift to ensure full uniform coverage.



5. As the paver places the adjacent pass, some slight spillage occurs from the overlap.



6. The spillage is then bumped back into the new uncompacted pass so the roller can compact it into the joint.



7. The joint and the remainder of the adjacent pass are then compacted.

Section Four Quiz

The term "mix quantity" refers to which of the following measurements? (Circle one)

a. Tons of mix placed
b. Cubic feet of mix places
c. Uncompacted depth of the mat
d. Compacted depth of the mat

When using a ten-foot straightedge to check the cross slope of a mat that is specified to have a cross slope of 0.025 feet/foot, the vertical measurement should be about … (Circle one)

e. … 0.025 feet.
f. … 0.050 feet.
g. … 0.250 feet.
h. … 0.500 feet.

2. Any mat thickness adjustments that are made should be based **primarily** on the … (Circle one)

a. ... Mat thickness checks
b. ... Calculated spread rates
c. ... Cross-slope checks
d. ... Judgment of the paver operator

For mat thickness checks on a two-inch lift of ¾-inch AC, the collar of the probe should be set at approximately ... (Circle one or more)

e. … ¾ inches
f. … 1-½ inches
g. … 2 inches
h. … 2-½ inches
i. … 3 inches

Whenever mat thickness adjustments are needed, they should be made using the … (Circle one)

j. … Manual mat thickness controls
k. … Grade sensor control screw
l. … Grade control knob on the operator's command panel
m. Any of the above methods

Longitudinal joints in successive lifts must be ... (Circle one or more)

n. … Staggered no more than two feet from each other.
o. … Staggered at least one foot from each other.
p. … Located within two feet from the center of a lane or the centerline between two or the centerline between two adjacent lanes.
q. … Located within one foot from the center of a lane or the centerline between two or the centerline between two adjacent lanes.

3. When resuming paving operations the next day at a transverse joint, which of the following steps should be done **first**? (Circle one)
   a. Remove the temporary taper.
   b. Position the paver at the joint with the screed blocked to the proper height.
   c. Straightedge the mat next to the joint.
   d. Tack the joint.

4. Which of the following methods of constructing a longitudinal joint is **not** acceptable? (Circle one or more)
   a. Hot vertical joint
   b. Cold vertical joint
   c. Hot sloped joint
   d. Cold sloped joint

Section Four Quiz Answers

1. a. Tons of mix placed

2. c. ... 0.25 feet.

3. b. Calculated spread rates

4. d. ... 2-½ inches

5. b. .... tGrade control screws.
   (**Note**: Possible with "c. .... Grade control knob on the operator's command panel," but this approach is usually more difficult.)

6. b. ... Staggered at least one foot from each other
   d. ... Located within one foot from the center of a lane or the centerline between two adjacent lanes.

7. c. Straightedge the mat next to the joint.

8. b. Cold vertical joint

Notes

Fourth Discussion Period
(Inspecting Rolling Operations and Documentation)

Section Five: Inspecting Rolling Operations

This section reviews the inspection of rolling operations in terms of:

- An overview of standard compaction requirements
- Basic rolling procedures
- Rolling method procedure for compaction
- General rules of rolling
- Inspecting compacted pavement

Standard Compaction Requirements

The rolling method procedure for compaction:

- Is always used on all bituminous pavement courses that are 1-½ inches or less in thickness.
- May be used in miscellaneous areas regardless of the thickness at the discretion of the Engineer.
- Is directed by the Engineer.

The End-Product Method is used only for AC (406, 416, and 417) and RAC (408) courses that are more than 1-½ inches in thickness and is directed by the Contractor.

Basic Rolling Procedures

Such basic procedures as how the roller gets on to the mat, the speed, and direction of the rollers, and the rolling patterns used are generally applicable to any rolling operation.

A **pass** is defined as one movement of the roller in either direction.

A **coverage** is defined as the number of passes as are necessary to cover the entire width being paved (ribbon).

Entry onto the Mat

The primary concern in getting the roller onto the mat is to avoid breaking the edge of the mat. This can be done by entering:

- From existing adjacent pavement
- On boards at the outside edge of a previously compacted mat
- At a tapered end of the uncompacted mat

Manufacturer's Recommendations

All compaction equipment should be operated in accordance with the manufacturer's recommendations. The Inspector should see that the manufacturer's specifications and recommended procedures are followed, particularly in such areas as ballasting, operating speeds and operation of vibrators.

Roller Speed

As a general rule, the roller should move slowly enough so that it does an effective job of compacting. Although the effective speeds of rollers may vary by type, make and model, for most models:

- Steel-wheel rollers should usually be limited to about 3 mph.
- Pneumatic-tire rollers usually should be limited to about 5 mph.

If rollers are having difficulty keeping up with pavement operations and the specified mat temperature, it is more effective to use additional rollers than to exceed the manufacturer's specified rolling speeds.

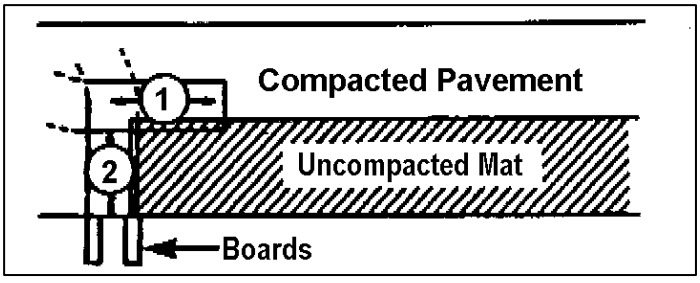
Basic Rolling Patterns

Generally acceptable patterns for rolling are summarized on the following pages in terms of:

- Rolling transverse and longitudinal joints
- Rolling the remainder of the mat

To roll transverse and longitudinal joints[5]:

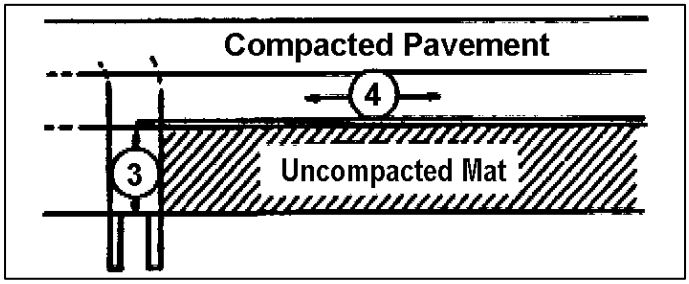
1. Pinch about 6 inches of the longitudinal joint along several feet of the joint.



2. Pinch about 6 inches of the entire transverse joint, using boards at the edge of the mat to avoid breaking the edge.

[5] Although the process documented here is commonly used, refer to Section 17 of the *Hot-Mix Asphalt Paving Handbook 2000* for an improved method of rolling transverse and longitudinal joints.

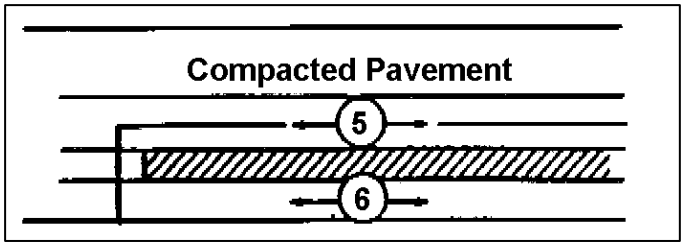
3. Half-lap the entire transverse joint (again using the boards to protect the edge).



4. Pinch about 6 inches of the remainder of the longitudinal joint.

   NOTE: The roller should be used only in the static mode on cold pavement.

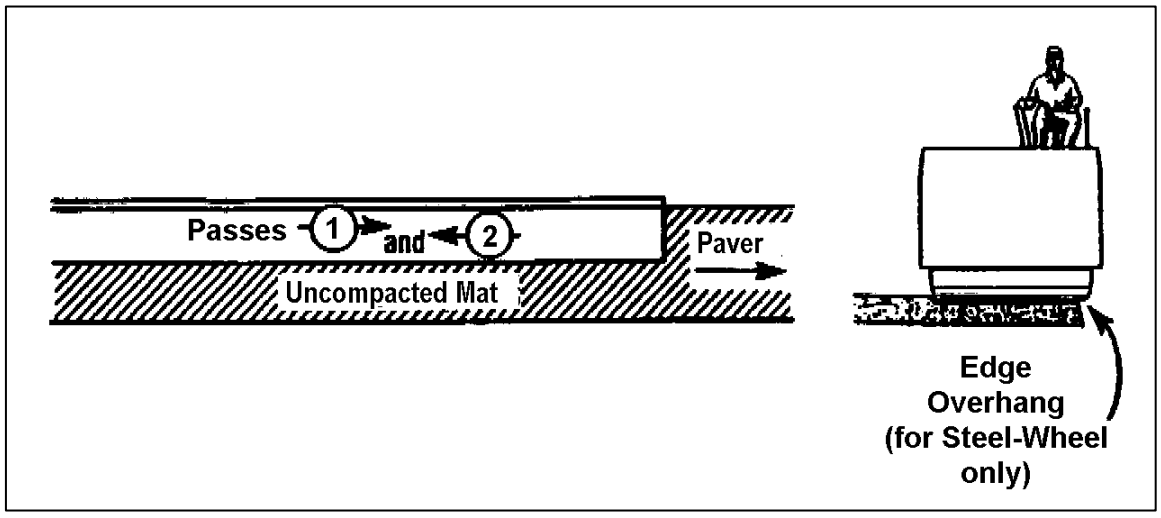
5. Overlap the entire longitudinal joint.



6. Roll the remainder of the mat (following the basic pattern as summarized below).

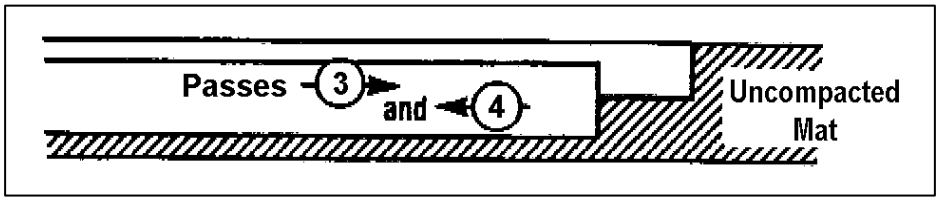
To roll the remainder of the mat (with or without joints):

1. Start at the lower edge of the mat with a slight overhang at the edge (for steel-wheel, but not pneumatic rollers).



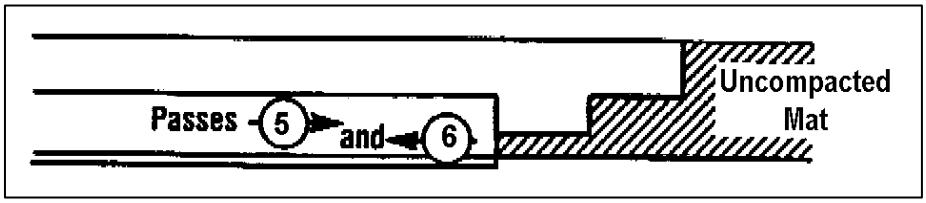
2. Reverse near the paver and follow the same path back.

3. The third pass overlaps the path of the first two passes.



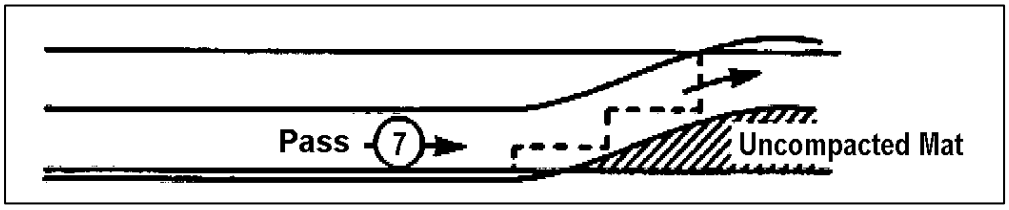
4. The reversal point to start the fourth pass is staggered short of the previous passes.

5. The overlapping continues to the higher edge of the mat.



6. Similarly, the reversal points are staggered short of the previous passes until the full width of the mat has been covered.

7. The roller then crosses over the staggered reversal points to remove the previous roller marks and position itself along the lower edge for the next section.



Note: There should always be an odd number of passes.

Method Rolling

The three basic phases of compaction by the method rolling procedure are:

1. Initial
2. Intermediate
3. Finish

Initial Rolling

Initial rolling – or "breakdown" rolling as it is also called – does most of the compaction in terms of the final density of the pavement. The key aspects to watch for in the initial phase of rolling are that:

- A steel-wheel roller is used, but a vibratory steel-wheel roller may be used if the nominal mat thickness is more than one inch.
- The initial rolling must keep up with the paving operation so that the mat is still hot (above the minimum specification prior to compaction temperature) and flexible.
- The basic rolling pattern is followed including:
  - Pinching and overlapping the joints
  - Providing a slight overhang at the edge
  - Working from the lower to the higher edge of the mat
  - Overlapping the previous passes
  - Staggering the reversal points
  - Crossing over the staggered reversal points

Intermediate Rolling

The purpose of intermediate rolling is to knit the finer aggregate particles around the coarse aggregates. The key points to watch for are that:

- Pneumatic-tired or vibratory steel-wheel may be used on AC and RAC courses.
- Pneumatic-tired rollers are not allowed on ACFC, AR-AC, or AR-ACFC courses.
- For AC and Miscellaneous Structural AC courses, the temperature of the mat is still at least 200° F.
- For RAC courses, the temperature of the mat is still at least 220° F.
- The rollers complete the specified number of passes.
- The same basic rolling pattern is followed **except** the rollers should avoid reversing at the same reversal points used in initial rolling.

Finish Rolling

The independent wheels of the pneumatic rollers used in intermediate rolling tend to leave slight "ridges" and "valleys" in the surface of the mat. The primary purpose of finish rolling is to remove such marks from previous rolling and smooth the surface. Key aspects of finish rolling are:

- Steel-wheel rollers must be used (excluding any vibratory mode).
- For AC, RAC, and Miscellaneous Structural AC courses, the mat should still be warm (not less than 180° F).
- For AR-AC and AR-ACFC courses, finish rolling must be completed before the temperature of the mat falls below 220° F.
- The same basic rolling pattern, as in initial rolling, is followed, **except** from one to three coverages are needed.
- The Inspector should inspect the surface during finish rolling for:
  - Any remaining roller or screed marks
  - Any fat (bleeding) or lean spots
  - A uniform surface texture

Method Rolling Acceptance

Compaction under the method rolling procedure is deemed acceptable **only after all** of the following conditions are met:

- The specified type and number of compactors are used.
- The compactors are ballasted and operated as specified.
- The specified number of coverages for each phase of rolling are performed.

End Product Method Acceptance

For lifts of AC more than 1-½ inches in nominal thickness, an end product method is used. Key aspects of the end product method are as follows:

- Determination of the types and numbers of rollers and number of coverages to be made is the responsibility of the Contractor;
- Usually the Contractor will use:
  - Vibratory steel-wheel rollers in the initial phase
  - Pneumatic-tired rollers in the intermediate phase
  - Steel-wheel rollers in the static mode for finish rolling

- Acceptance of AC mats compacted by the end product method is based on the density of each lot with:
  - A lot is the result of one day's production.
  - Duplicate cores taken at 10 random locations (10 cores for acceptance testing and 10 cores for referee testing) for 416 and 417, (for 406 only one core at each of 10 random locations is taken).
  - Four random plate samples taken from the mat immediately behind the laydown machine for 406, 416, and 417 mixtures.
  - Acceptability for 406 and 416 without penalty is having 90 percent or more (PT-90 or greater) of the bulk densities of the 10 cores falling within the upper and lower limits of acceptable production, which is 98.0 percent of the average laboratory Marshall density ± 4.0 pounds as determined from the plate samples. (Acceptability for 417 is based on 4.0 to 9.0 percent in-place air voids.)
  - Compaction pay factors provided when the total percentage of the lot within the acceptable production limits (PT) falls between 50 and 100 percent (see table 406-2, table 416-2, or table 417-4 in the specifications).
  - Rejection of a compaction lot occurring when the percentage of lot compliance is less than 50 percent (PT-49 or less) and requiring an Engineering Analysis to be submitted by the Contractor and accepted by the Engineer for the material to remain in place (referee results for 416 and 417 may bring the lot out of reject status).
  - Referee testing for 416 and 417 by an independent testing laboratory as an option for Contractors who question the compaction test results of a particular lot whether or not that particular lot is in reject status.

- Acceptance of RAC mats compacted by the end product method are the same as 406 and 416 AC mats except that:
  - Only a single core is taken at each of 10 random locations.
  - Only 3 plate samples are taken from the mat.
  - Acceptability is based on having 80 percent or more (PT-80 or greater) of the bulk densities of the 10 cores falling within the upper and lower limits of acceptable production, which is 98.0 percent of the average laboratory Marshall density ± 4.5 pounds as determined from the three plate samples.
  - There are no compaction pay factors.
  - There is no referee testing option.

- Work shall cease if more than two lots in 5 consecutive lots fail to meet the fore mentioned 80 percent of the lot in compliance criteria. At this time, the Contractor will examine his compaction procedures and implement corrective action on one more shift. If this shift fails, the Engineer may direct a test section to determine if the specified compaction requirements are attainable. If the requirements are not attainable, revised requirements will be established (new target value and/or percent of lot compliance).

Rules of Rolling

Whether the mat is compacted by the method rolling method or the end product method, there are several basic rules of effective rolling. Rollers should **always**:

- Be operated in accordance with the manufacturer's recommendations.
- Be operated slowly enough to be effective (see page 185 of *Hot-Mix Asphaltic Paving Handbook 2000*).
- Keep up with paving operations on initial rolling.
- Have all wheels and tires wiped when necessary with an approved product to prevent picking up material.
- Have skirts on all pneumatic rollers.

Rollers should **avoid**:

- Sudden "gunning" or "braking" of the rollers
- Sharp turns on the mat
- Mix piling up in front of the roller
- Sinking into the mat
- Parking on an uncompacted or a recently compacted (and still warm) mat

Inspecting Finished Pavement

After the mat has been compacted, the Inspector must:

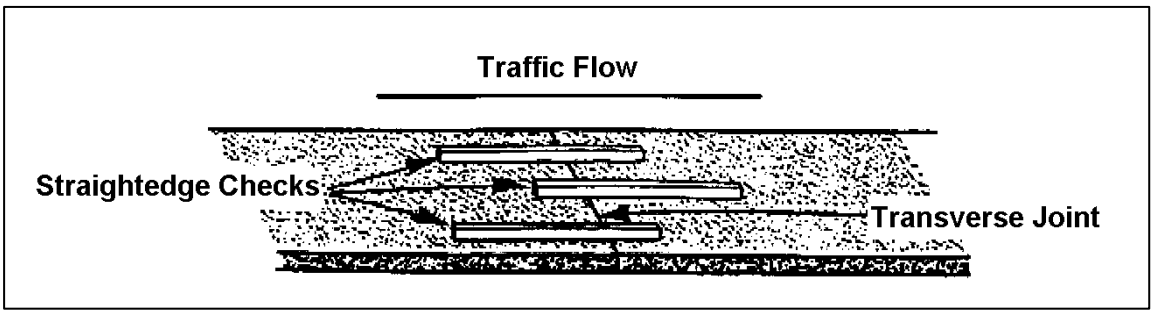
- Straightedge the surface to see that it is within the specified tolerances.
- Check the cross slopes and crown of the pavement.
- Inspect the surface for smooth, uniform texture.
- See that the Contractor cleans up the work area.

Straightedging

Straightedging must be done with a ten-foot manual straightedge. The locations to be straightedged are:

- All transverse joints
- At random locations across longitudinal joints
- At random longitudinal locations throughout the pavement

At each location, several checks should be made. For all checks (except those across longitudinal joints), the straightedge is placed parallel to the direction of the traffic flow.



Note: Straightedging across a transverse joint is done in the longitudinal direction.

The specified tolerances for straightedging are:

- Maximum of ¼ inch per 10 feet parallel to the centerline for leveling courses of Recycled AC, AR-AC
- Maximum of ⅛ inch per 10 feet, parallel to the centerline for:
  - AC, Recycled AC, and AR-AC surface courses
  - ACFC and AR-ACFC

The specification tolerance is ¼ inch per 10 feet for straightedge checks across longitudinal joints. However, longitudinal joints at the crown point cannot be checked with a straightedge. Do not forget to check longitudinal joints at the centerline where the roadway is fully super-elevated for a curve.

When the project is finished, ADOT Materials Group, Pavement Management Section will perform smoothness testing for evaluation of the smoothness bonus/penalty if called for in the contract.

Cross-Slope Checks

As previously discussed in Section Four, the cross-slope of the mat first should be checked before compaction so that any deviations can be identified and corrected before they become serious problems. However, incorrect rolling of the mat can sometimes cause the mat to shift, so it is good practice to recheck the cross-slope after the mat has been compacted.

The same tools and procedures used in checking the fresh mat can be used in re-checking the compacted mat including:

1. Placing the straightedge across the pavement
2. Using the spirit level to get the straightedge level
3. Measuring the vertical distance from the end of the straightedge to the pavement surface

Surface Texture

The surface of the finished mat should be smooth – but **not** slick. Some natural texture is expected and desirable, but it should be uniform – **not** irregular. There should be:

- **No** pulled or torn areas
- **No** streaks or gouges
- **No** rock pockets or sand spots
- **No** spots that are rich or lean with asphalt

Final Clean-Up

The finished pavement should be allowed time to fully cool before it is opened to traffic. During this time, do not let the Contractor:

- Stockpile materials on it
- Drive/park vehicles or equipment on it

The Inspector must see that the Contractor cleans up the paving work areas – including the complete removal and disposal of such waste materials as piles of cold wasted mix.

Tender Mixes

A tender mix exhibits instability during or after the compaction process and usually occurs in hot weather. The signs of a tender mix are:

- Lateral movement of the mix (instability)
- Inability to reach the specified density regardless of the number of passes or the variety of different types of compactors employed

The instability symptoms sometimes disappear as the mix temperature drops or they may be present when the mix is at ambient temperature. An inability to reach density does not always indicate a tender mix. If the Engineer suspects a tender mix, he should contact the Pavement Materials Testing Section of ADOT's Materials Group.

Section Five Quiz

For which of the following bituminous paving applications would the rolling method be used? (Circle one or more)

2. AC with a nominal mat thickness of more than 1-½ inches placed in misc. areas if so directed by the Project Engineer.
3. AC with a nominal mat thickness of more than 1-½ inches, unless otherwise directed by the Project Engineer.
4. AC with a nominal mat thickness of 1-½ inches or less.
5. ACFC.
6. Recycled AC with a nominal mat thickness of 1-½ inches or less.

For which of the following bituminous paving operations would the end product method of compaction be used? (Circle one or more)

7. RAC with a nominal mat thickness of more than 1-½ inches.
8. AC with a nominal mat thickness of more than 1-½ inches, unless otherwise directed by the Project Engineer.
9. AC with a nominal mat thickness of 1-½ inches or less.
10. ACFC.
11. Recycled AC with a nominal mat thickness of 1-½ inches or less.

In the basic rolling pattern without any joints, the roller should start ... (Circle one)

12. ... At the higher edge of the mat.
13. ... In the center of the mat.
14. ... At the lower edge of the mat.
15. ... At either edge of the mat.

16. In rolling a transverse joint, the roller should **first** ... (Circle one)
17. ... Roll across the joint parallel to the edge of the mat.
18. ... Pinch about 6 inches of the fresh mat along the joint moving across the mat.
19. … Half-lap along the joint moving across the mat.

In method rolling, the initial and intermediate phases must be completed before the temperature of the mat falls below ... (Circle one)

20. … 300° F
21. … 240° F
22. … 200° F
23. … 140° F

In method rolling, the finish phase is done with ... (Circle one)

24. ... One coverage of a vibratory, steel-wheel roller.
25. ... 1 to 3 coverages with a static, steel-wheel roller.
26. ... 4 to 9 coverages (depending on the nominal thickness of the mat) with a pneumatic-tired roller.
27. … Any type of roller and numbers of passes as long as the nuclear density readings are satisfactory.

In the end product method of rolling, which of the following types of rollers is required? (Circle one or more)

28. Vibratory, steel-wheel
29. Static, steel-wheel
30. Pneumatic-tired
31. Any of the above types may be used as long as the specified percent density is achieved

Section Five Quiz Answers

1. a. AC with a nominal mat thickness of more than 1-½ inches if so directed by the Project Engineer.
   c. AC with a nominal mat thickness of 1-½ inches or less.
   d. ACFC.
   e. Recycled AC with a nominal mat thickness of 1-½ or less.

2. a. RAC with a nominal mat thickness of more than 1-½ inches.
   b. AC with a nominal mat thickness of more than 1-½ inches, unless otherwise directed by the Project Engineer.

3. c. At the lower edge of the mat.

4. b. Pinch about 6 inches of the fresh mat along the joint moving across the mat.

5. c. … 200° F

6. b. … 1 to 3 coverages with a static, steel-wheel roller.

7. d. Any of the above types may be used as long as the specified percent density is achieved.

Section Six: Documentation

This section summarizes the documentation involved in inspecting asphaltic concrete paving operations in terms of:

- Measurement as the basis for payment
- Key information and events to be documented
- The records and reports used

Measurement for Payment

The key measurements used as the basis for payment for Asphaltic Concrete, Asphaltic Concrete Friction Course, and Recycled Asphaltic Concrete are the tons of mix actually used. These quantities are based primarily on the weight tickets of the loads of mix as dispatched from the plant and accepted at the roadway.

Depending on the results of the testing of the in-place compacted AC pavement (cores), pay factor adjustments for compaction may be made for 406, 416, and 417 mixtures. Pay factor adjustments for the quality of the mix may be made for 406, 416, and 417 mixtures, depending on the test results for the AC mix quality (plate samples). See the corresponding sections of the specifications for details.

Traffic control for paving operations is measured and paid for as specified in Section 701.

Key Information and Events

Some of the key information and events that need to be documented for paving operations are similar to that of any construction work including:

- Routine information, such as the type of work being done, the project, the location, the time of the work, and the weather; and
- Special events or problems, including any unusual conditions, instructions to the Contractor, rejected work or materials, and corrective actions taken by the Contractor.

Other key items of information and events that need to be documented specifically for paving operations include:

- Information on samples taken and test results for:
  - Bituminous material used for tack
  - Bituminous mix
- Types and quantities of materials delivered to the project including bituminous material used for tack and bituminous mix

- Information from inspecting equipment and other preparations including:
  - Any deviations or problems with the traffic control plan
  - Types of alignment and grade control systems used
  - Types of loading system, screed, and automatic controls used on the paver
  - Manufacturer's recommendations for ballasting and operation of the rollers used
  - Weather conditions at the start of and during operations
- Checks of the temperature of the mix, mat thickness, cross slope spread rate, and surface tolerances (with particular attention to any deficiencies found and the corrective actions taken)
- Information on joint construction including the:
  - Locations of transverse joints and the methods used
  - Methods used for longitudinal joints
- Information on compaction including the:
  - Types, makes, models, and numbers of rollers used
  - Mat temperatures immediately before and during compaction
  - The number of coverages made for each phase in method rolling
- Locations and types of any surface tolerance, mat quality, or other deficiencies found in inspecting the pavement after compaction

Records and Reports

The principal records and reports used in documenting asphaltic concrete paving operations are:

- Daily Diary
- Documents on the sampling and testing of materials
- Project Asphalt Record
- Weight tickets and spread sheets for the mix
- Summary reports used in final documentation at the end of the project

Your instructor should be able to provide copies of examples of most of these records and reports. The ADOT Construction Manual will provide additional information on documentation requirements.

Daily Diary

The Daily Diary serves as both a record and a report of all key events that occur during the day. All Daily Diaries are the property of the Department and serve as the foundation of all construction project records, so they must be maintained neatly and legibly in ink. They are generally a summary of key events and information, but they must provide sufficient detail so that other personnel can get an accurate picture of what happened each day.

The items recorded in the Daily Diary include:

- Routine information
  - Identification of the project
  - Type of work being done
  - Location of the work
  - Times work is started/stopped
  - Weather conditions
  - Any important phone calls or other communications sent or received
  - An inventory of the Contractor's equipment and personnel resources being used on the work
- Information on any special events or problems encountered such as:
  - Any official visitors to the project
  - Unusual conditions that may affect the work
  - Times/causes of any delays
  - Important discussions with the Contractor any specific instructions or orders given
  - Rejection of any materials or work including the reasons for the rejection
  - Any changes, adjustments or corrective actions by the Contractor
  - Any other information that may be relevant to any potential disputes or claim
- Summaries of the paving work completed during the day including:
  - Locations paved
  - Tons of mix used
  - Spread rates
- Key events in the day's paving operations
  - Times and causes of any periods of work shut down
  - Any significant changes or adjustments made in methods being used at the paving site
  - Any other actions taken by the Contractor or ADOT at the paving site or the plant that may affect the pavement

- Field notes[6] for asphaltic concrete paving, used to record detailed technical information on the work including:
  - Information on the types, quantities and adjustable settings of equipment used at the paving site
  - Calculations used in determining such data as total quantities of mix used and spread rate
  - Any sketches or diagrams as may be needed to clarity such data as the calculations of spread rates for turn-outs or other special areas

Sampling and Testing Documents

The Inspector must see that all samples are properly identified with sample tags and all field test results are properly recorded. For additional information on the documentation of specific sampling and testing procedures, see *Field Sampling and Testing for Bituminous Construction* (Course 301).

Project Asphalt Record

The Project Asphalt Record is specifically designed to record, calculate, and report the quantities and spread rates of bituminous material used in tack coats and other bituminous treatments. For additional information on the Project Asphalt Record, see *Prime, Flush and Tack Coats Inspection* (Course 302).

Weight Tickets and Spread Sheets

Because asphaltic concrete is paid for on the basis of the tons of mix used **and** because each pavement course is designed in terms of a specified mat thickness, the weight tickets and spread sheets for the mix are two of the most critical documents involved in asphaltic concrete paving.

As each load of mix is delivered to the project, the Inspector must collect the weight ticket that certifies the quantity of material delivered. Because these quantities serve as the primary basis for payment – and are used in determining spread rates – the Inspector must take care to see that they are accurate and that they are maintained as part of the project records. The total quantities of mix from the individual weight tickets should be periodically cross-checked with the quantities dispatched from the plant as documented in the Scaler's weight sheet.

It is extremely important for the Inspector to calculate and document the actual spread rates of the mix as it is placed. Since the Contractor is paid on the basis of the tons of mix used, it is generally to his financial advantage to use more than is actually needed. But too much mix is a waste of material in relation to the needs of the roadway. If the Inspector does not closely monitor the actual spread rate of the mix in relation to the designed mat thickness, the job can cost more than planned, but without any significantly higher quality in the finished product.

[6] Because they are a key part of the Department's permanent record of the work, all field notes must be neat, clear, and accurate.

A variety of different formats are currently in use for calculating and documenting the spread rate of bituminous mix, but the key elements are basically the same as outlined below.

1. **At the Start** of the operations, record:
   - Time
   - Station number
   - Width of the paving course

2. **As each load of mix is delivered,** record:
   - Truck number
   - Tons of mix being delivered (from the weight ticket)
   - Station number

3. After at least **every fifth load:**
   - Record the time and station number
   - Calculate and record:
     - Tons of mix used
     - Area covered
     - Actual spread rate (by dividing the tons used by the area covered and converting ton/sq. yd. into lbs./sq. yd.)
     - Average mat thickness with the designed thickness

4. **At the end of each spread lot (twice per day)**, calculate the spread lot:
   - Total tons of mix used
   - Total area covered
   - Average mat thickness

Using this basic spread-rate procedure, at any given time the Inspector can know the quantities of mix used on the project. With this knowledge, the Inspector can control the:

- Quality of the pavement in relation to the designed mat thickness
- Quantities and costs of the project to date in relation to the total planned quantities and budget

Final Documentation

At the end of the project, the Project Engineer prepares a Final Project Report. The paving Inspector's records and reports provide vital input for this report and the paving Inspector may often be needed to assist in compiling the data for the report particularly in relation to the:

- Total quantities of mix placed
- Average mat thicknesses at various locations
- Overall effectiveness of the Contractor's paving operations

Appendix
Temperature-Volume Corrections for Asphaltic Materials

Group 0 – Specific Gravity at 60° F Above 0.966

LEGEND: t = observed temperature in degrees Fahrenheit
M = multiplier for correcting asphalt cement volumes to the basis of 60° F

t	M	t	M	t	M	t	M	t	M	t	M	t	M	t	M	t	M	t	M
0	0.0211	50	1.0035	100	0.9861	150	0.9689	200	0.9520	250	0.9352	300	0.9187	350	0.9024	400	0.8864	450	0.8705
1	1.0200	51	1.0031	101	0.9857	151	0.9686	201	0.9516	251	0.9349	301	0.9184	351	0.9021	401	0.8861	451	0.8702
2	1.0204	52	1.0028	102	0.9854	152	0.9682	202	0.9513	252	0.9346	302	0.9181	352	0.9018	402	0.8857	452	0.8699
3	1.0201	53	1.0024	103	0.9851	153	0.0969	203	0.9509	253	0.9342	303	0.9177	353	0.9015	403	0.8854	453	0.8696
4	1.0197	54	1.0021	104	0.9847	154	0.9675	204	0.9506	254	0.9339	304	0.9174	354	0.9011	404	0.8851	454	0.8693
5	1.0194	55	1.0017	105	0.9844	155	0.9672	205	0.9503	255	0.9336	305	0.9171	355	0.9008	405	0.8848	455	0.8690
6	1.0190	56	1.0014	106	0.9840	156	0.9669	206	0.9499	256	0.9332	306	0.9167	356	0.9005	406	0.8845	456	0.8687
7	1.0186	57	1.0010	107	0.9837	157	0.9665	207	0.9496	257	0.9329	307	0.9164	357	0.9002	407	0.8841	457	0.8683
8	1.0183	58	1.0007	108	0.9833	158	0.9662	208	0.9493	258	0.9326	308	0.9161	358	0.8998	408	0.8838	458	0.8680
9	1.0179	59	1.0003	109	0.9830	159	0.9658	209	0.9489	259	0.9322	309	0.9158	359	0.8995	409	0.8835	459	0.8677
10	1.0176	60	1.0000	110	0.9826	160	0.9655	210	0.9486	260	0.9319	310	0.9154	360	0.8992	410	0.8832	460	0.8674
11	1.0172	61	0.9997	111	0.9823	161	0.9652	211	0.9483	261	0.9316	311	0.9151	361	0.9889	411	0.8829	461	0.8671
12	1.0169	62	0.9993	112	0.9819	162	0.9648	212	0.9479	262	0.9312	312	0.9148	362	0.8986	412	0.8826	462	0.8668
13	1.0165	63	0.9990	113	0.9816	163	0.9645	213	0.9476	263	0.9309	313	0.9145	363	0.8982	413	0.8822	463	0.8665
14	1.0162	64	0.9986	114	0.9813	164	0.9641	214	0.9472	264	0.9306	314	0.9141	364	0.8979	414	0.8819	464	0.8661
15	1.0158	65	0.9983	115	0.9809	165	0.9638	215	0.9469	265	0.9302	315	0.9138	365	0.8976	415	0.8816	465	0.8658
16	1.0155	66	0.9979	116	0.9806	166	0.9635	216	0.9466	266	0.9299	316	0.9135	366	0.8973	416	0.8813	466	0.8655
17	1.0151	67	0.9976	117	0.9802	167	0.9631	217	0.9462	267	0.9296	317	0.9132	367	0.8969	417	0.8810	467	0.8652
18	1.0148	68	0.9972	118	0.9799	168	0.9628	218	0.9459	268	0.9293	318	0.9128	368	0.8966	418	0.8806	468	0.8649
19	1.0144	69	0.9969	119	0.9795	169	0.9624	219	0.9456	269	0.9289	319	0.9125	369	0.8963	419	0.8803	469	0.8646
20	1.0141	70	0.9965	120	0.9792	170	0.9621	220	0.9452	270	0.9286	320	0.9122	370	0.8960	420	0.8800	470	0.8643
21	1.0137	71	0.9962	121	0.9788	171	0.9618	221	0.9449	271	0.9283	321	0.9118	371	0.8957	421	0.8797	471	0.8640
22	1.0133	72	0.9958	122	0.9785	172	0.9614	222	0.9446	272	0.9279	322	0.9115	372	0.8953	422	0.9794	472	0.8636
23	1.0130	73	0.9955	123	0.9782	173	0.9611	223	0.9442	273	0.9276	323	0.9112	373	0.8950	423	0.9791	473	0.8633
24	1.0126	74	0.9951	124	0.9778	174	0.9607	224	0.9439	274	0.9273	324	0.9109	374	0.8947	424	0.8787	474	0.8630
25	1.0123	75	0.9948	125	0.9775	175	0.9604	225	0.9436	275	0.9269	325	0.9105	375	0.8944	425	0.8784	475	0.8627
26	1.0119	76	0.9944	126	0.9771	176	0.9601	226	0.9432	276	0.9266	326	0.9102	376	0.8941	426	0.8781	476	0.8624
27	1.0116	77	0.9941	127	0.9768	177	0.9597	227	0.9429	277	0.9263	327	0.9099	377	0.8937	427	0.8778	477	0.8621
28	1.0112	78	0.9937	128	0.9764	178	0.9594	228	0.9426	278	0.9259	328	0.9096	378	0.8934	428	0.8775	478	0.8618
29	1.0109	79	0.9934	129	0.9761	179	0.9590	229	0.9422	279	0.9256	329	0.9092	379	0.8931	429	0.8772	479	0.8615
30	1.0105	80	0.9930	130	9.7558	180	0.9587	230	0.9419	280	0.9253	330	0.9089	380	0.8928	430	0.8768	480	0.8611
31	1.0102	81	0.9927	131	0.9754	181	0.9584	231	0.9416	281	0.9250	331	0.9086	381	0.8924	431	0.8765	481	0.8608
32	1.0098	82	0.9923	132	0.9751	182	0.9580	232	0.9412	282	0.9246	332	0.9083	382	0.8921	432	0.8762	482	0.8605
33	1.0095	83	0.9920	133	0.9747	183	0.9577	233	0.9409	283	0.9243	333	0.9079	383	0.8918	433	0.8759	483	0.8602
34	1.0091	84	0.9916	134	0.9744	184	0.9574	234	0.9405	284	0.9240	334	0.9076	384	0.8915	434	0.8756	484	0.8599
35	1.0088	85	0.9913	135	0.9740	185	0.9570	235	0.9402	285	0.9236	335	0.9073	385	0.8912	435	0.8753	485	0.8596
36	1.0084	86	0.9909	136	0.9737	186	0.9567	236	0.9399	286	0.9233	336	0.9070	386	0.8908	436	0.8749	486	0.8593
37	1.0081	87	0.9906	137	0.9734	187	0.9563	237	0.9395	287	0.9230	337	0.9066	387	0.8905	437	0.8746	487	0.8590
38	1.0077	88	0.9902	138	0.9730	188	0.9560	238	0.9392	288	0.9227	338	0.9063	388	0.8902	438	0.8743	488	0.8587
39	1.0074	89	0.9899	139	0.9727	189	0.9557	239	0.9389	289	0.9223	339	0.9060	389	0.8899	439	0.8740	489	0.8583
40	1.0070	90	0.9896	140	0.9723	190	0.9553	240	0.9385	290	0.9220	340	0.9057	390	0.8896	440	0.8737	490	0.8580
41	1.0067	91	0.9892	141	0.9720	191	0.9550	241	0.9382	291	0.9217	341	0.9053	391	0.8892	441	0.8734	491	0.8577
42	1.0063	92	0.9889	142	0.9716	192	0.9547	242	0.9379	292	0.9213	342	0.9050	392	0.8889	442	0.8731	492	0.8574
43	1.0060	93	0.9885	143	0.9713	193	0.9543	243	0.9375	293	0.9210	343	0.9047	393	0.8886	443	0.8727	493	0.8571
44	1.0056	94	0.9882	144	0.9710	194	0.9540	244	0.9372	294	0.9207	344	0.9044	394	0.8883	444	0.8724	494	0.8568
45	1.0053	95	0.9879	145	0.9706	195	0.9536	245	0.9369	295	0.9204	345	0.9040	395	0.8880	445	0.8721	495	0.8565
46	1.0049	96	0.9875	146	0.9703	196	0.9533	246	0.9365	296	0.9200	346	0.9037	396	0.8876	446	0.8718	496	0.8562
47	1.0046	97	0.9871	147	0.9699	197	0.9530	247	0.9362	297	0.9197	347	0.9034	397	0.8873	447	0.8715	497	0.8559
48	1.0042	98	0.9868	148	0.9696	198	0.9526	248	0.9359	298	0.9194	348	0.9031	398	0.8870	448	0.8712	498	0.8556
49	1.0038	99	0.9864	149	0.9693	199	0.9523	249	0.9356	299	0.9190	349	0.9028	399	0.8867	449	0.8709	499	0.8552